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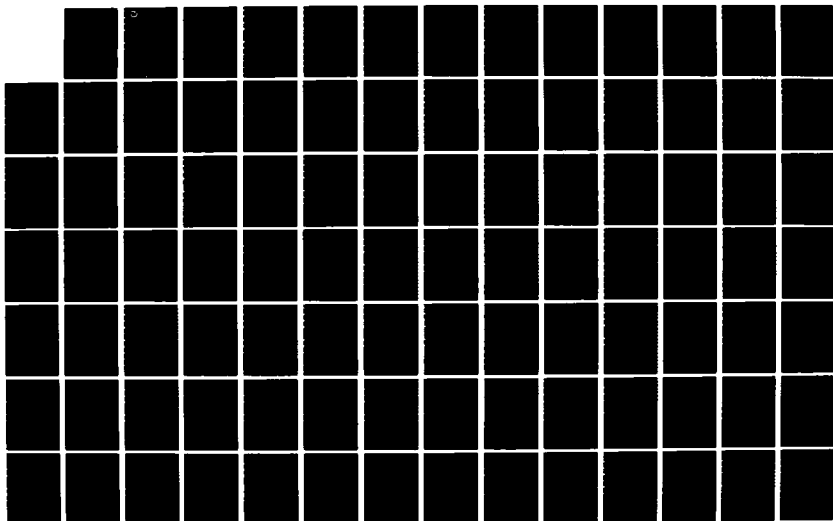
ADA (TRADE NAME) TRAINING CURRICULUM BASIC ADA  
PROGRAMMING L202 TEACHER'S GUIDE VOLUME 2(U) SOFTECH  
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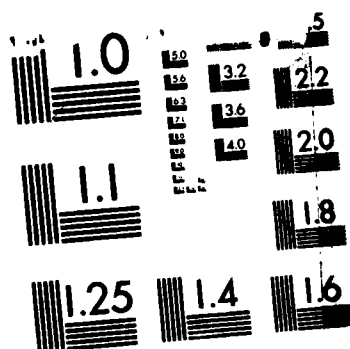
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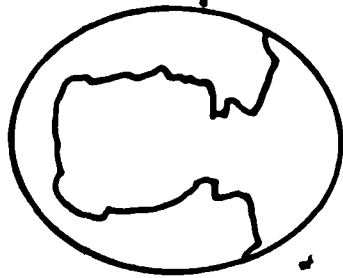
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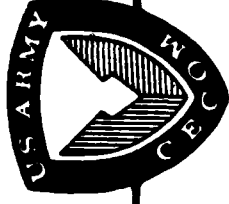


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1986

# Ada® Training Curriculum



## Basic Ada® Programming L202 Teacher's Guide Volume II

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**PART II**  
**BASIC Ada\* PROGRAMMING (L202)**  
**TEACHER'S GUIDE**



INSTRUCTOR NOTES

ALLOCATE AT LEAST ONE HOUR AND A HALF OF LECTURE FOR THIS SECTION.

ASSIGN EXERCISES 22 THROUGH 24 OF THE EXERCISE BOOKLET FOR LAB WORK. (PUT HIGHER STRESS ON 24.)

THE OBJECTIVE OF THIS SECTION IS TO INTRODUCE RECORD TYPES AND OBJECTS, RECORD AGGREGATES, OPERATIONS ON RECORD OBJECTS, AND RECORD ATTRIBUTES.

# SECTION 9 RECORD TYPES

Accession For	
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Justification	
By _____	
Distribution/	
Availability Codes	
Avail and/or	
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A-1	



## INSTRUCTOR NOTES

POINT OUT THAT ARRAYS ARE COMPOSITE OBJECTS ALSO, YET COMPONENTS OF ARRAYS MUST BE OF THE SAME TYPE. RECORD OBJECTS MAY HAVE COMPONENTS OF VARYING TYPES.

# RECORD

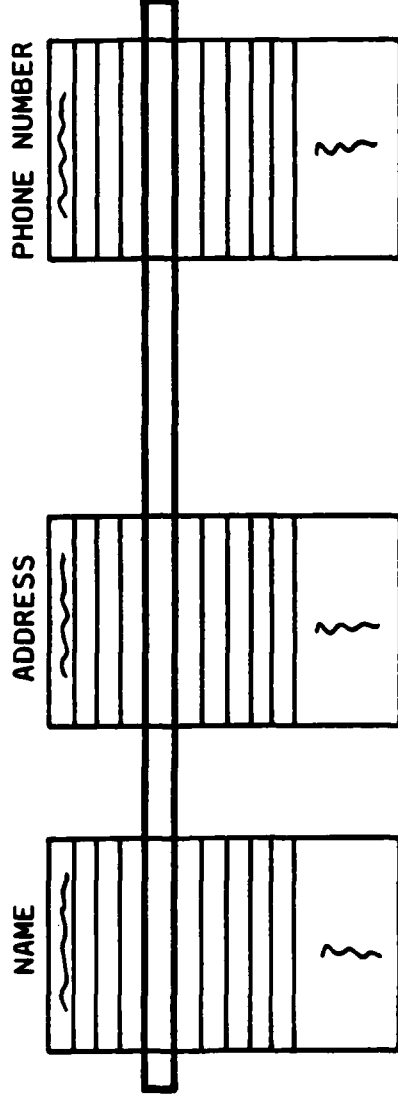
- IS A COMPOSITE OBJECT CONSISTING OF  
NAMED COMPONENTS  
WHICH MAY BE OF DIFFERENT TYPES
- SPECIFIES A LOGICAL RELATIONSHIP,  
NOT STORAGE LAYOUT

INSTRUCTOR NOTES

THE POINT IS THAT RECORDS ALLOW GROUPING TOGETHER OF LOGICALLY RELATED DATA ITEMS.

# ARRAY STRUCTURE

- ARRAY STRUCTURE IS LIMITING AS EACH COMPONENT MUST BE OF THE SAME TYPE.
- ARRAY STRUCTURE FOR NAME, ADDRESS, PHONE NUMBER...



- ARRAY VIEW DISALLOWS GROUPING OF ONE INDIVIDUAL'S DATA.
- RECORD VIEW ALLOWS GROUPING OF ONE INDIVIDUAL'S DATA.

## INSTRUCTOR NOTES

AN EXAMPLE BEFORE THE RULES ARE SPECIFIED.

POINT OUT THE RESERVED WORDS. EMPHASIZE THAT THE TYPE DECLARATION DEFINES A SET OF VALUES AND A SET OF OPERATIONS.

POINT OUT THE CONSTRAINT SUPPLIED TO THE COMPONENT BELONGING TO THE UNCONSTRAINED ARRAY TYPE STRING.

# RECORD TYPE DECLARATIONS

## EXAMPLE:

```
type Graphics_Op_Type is (Move, Line, Polygon);

type Instruction_Type is
  record
    Op : Graphics_Op_Type;
    X_Coord : Integer range 0 .. 319;
    Y_Coord : Integer range 0 .. 239;
  end record;

Maximum_Length : constant := 80;

type Buffer_Type is
  record
    Current_Length : Natural;
    Contents : String (1..Maximum_Length);
  end record;
```





# RECORD OBJECT DECLARATION

## CONTEXT:

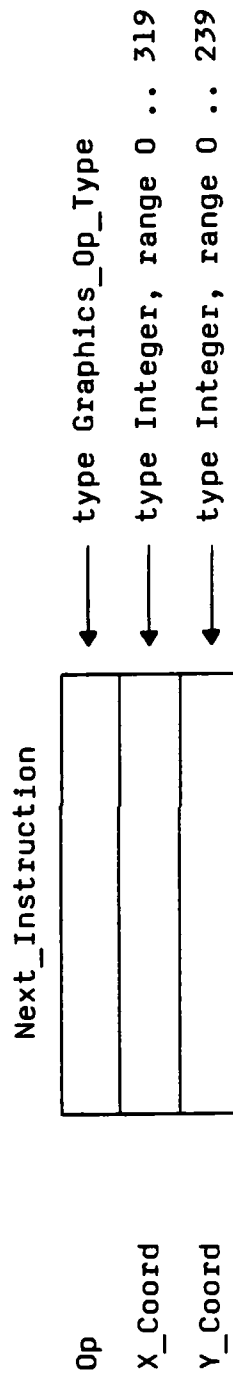
```
type Graphics_Op_Type is (Move, Line, Polygon);

type Instruction_Type is
  record
    Op : Graphics_Op_Type;
    X_Coord : Integer range 0 .. 319;
    Y_Coord : Integer range 0 .. 239;
  end record;
```

## EXAMPLE:

```
Next_Instruction : Instruction_Type;
```

## CREATES:



## INSTRUCTOR NOTES

THIS IS HOW TO GET A COMPONENT (PART) OF THE RECORD.

- POINT OUT THAT YOU CAN ACCESS A COMPONENT OF A COMPONENT.
- POINT OUT INITIALIZATION OF THE OBJECT Line\_Buffer.

# COMPONENT ACCESS

- USE DOT NOTATION TO ACCESS INDIVIDUAL COMPONENTS.

CONTEXT:

```
Maximum_Length : constant := 30;

type Buffer_Type is
  record
    Current_Length : Natural;
    Contents       : String (1..Maximum_Length) := (others => ' ');
  end record;

Line_Buffer : Buffer_Type := (Contents => "This is a line of text.",
                             Current_Length => 23);
```

EXAMPLE:

```
Line_Buffer.Current_Length -- 23
Line_Buffer.Contents       -- "This is a line of text."
Line_Buffer.Contents (1..4) -- "This"
```

# INSTRUCTOR NOTES

- MENTION THAT THE COMPONENT MAY BE ASSIGNED A DEFAULT INITIAL VALUE. DEFAULT INITIAL VALUES FOR COMPONENTS APPLY WHEN AN OBJECT DECLARATION DOES NOT SPECIFY A DEFAULT VALUE FOR THE ENTIRE RECORD OBJECT.
- MENTION THAT THIS IS A SIMPLE SYNTAX OF A RECORD.
- IF THE COMPONENT TYPE IS AN ARRAY TYPE, THE COMPONENT MUST BE CONSTRAINED. EITHER THE ARRAY TYPE OR SUBTYPE MUST BE CONSTRAINED OR THE COMPONENT TYPE NAME MUST BE ACCOMPANIED BY AN INDEX CONSTRAINT. I.E. IF String IS A COMPONENT TYPE IT MUST HAVE A BOUND SPECIFIED.

# RECORD TYPE DECLARATION

SYNTAX:

```
type Type_Name is
record
    Component_Name : Component_Type_or_Subtype_Name [:= Default_Initial_Value];
    { Component_Name : Component_Type_or_Subtype_Name [:= Default_Initial_Value];}
end record;
```

# INSTRUCTOR NOTES

- COMPONENTS OF TYPE STRING MUST HAVE A RANGE SPECIFIED.
- ARRAY COMPONENTS MUST BE OF AN ARRAY TYPE WHICH HAS BEEN PREVIOUSLY DEFINED.  
COMPONENTS OF ANONYMOUS ARRAY TYPES, E.G.

type Rec is

record

Comp: array (1 .. 10) of Boolean;

end record;

ARE ILLEGAL. THEY MAY SEE THIS IN OTHER REFERENCES. IT IS NO LONGER LEGAL. Ada  
80 ALLOWED IT.

# COMPONENTS

- MUST BE NAMED

- MAY BE OF ANY TYPE

- IF COMPONENT IS AN ARRAY IT MUST BE  
FULLY CONSTRAINED.

EITHER (1) THE COMPONENT MUST BELONG TO A  
CONSTRAINED ARRAY TYPE, OR

(2) THE COMPONENT MUST HAVE AN INDEX CONSTRAINT.

- ANONYMOUS ARRAY TYPE IS NOT A LEGAL COMPONENT.



INSTRUCTOR NOTES

A RECORD COMPONENT MUST BE CONSTRAINED.

# COMPONENT DECLARATIONS

-- LEGAL

type OK\_Record\_Type is

record

    Name\_Component : String (1 .. 20);   -- constraint supplied

end record;

-- \*\* ILLEGAL \*\*

CONTEXT:

type Matrix\_Type is array (Integer range <>, Integer range <>) of Integer;

(NON) EXAMPLE:

type Illegal\_Record\_Type is  
record

    Dimension : Positive;

    Matrix : Matrix\_Type;

end record;

-- not constrained

## INSTRUCTOR NOTES

- RECORD TYPES ARE THE ONLY TYPES WHICH ALLOW INITIAL VALUES FOR OBJECT COMPONENTS TO BE SPECIFIED IN THE TYPE DECLARATION.
- POINT OUT THAT NOT ALL THE COMPONENTS HAVE TO HAVE INITIAL VALUES. IN OTHER WORDS

type Rec is

record

C1: Integer;

C2: Boolean := True;

C3: Character;

end record;

IS LEGAL

- IT IS USUALLY BETTER PROGRAMMING PRACTICE TO REFER TO THE BASE TYPE IN A RANGE CONSTRAINT, THUS THE Minutes\_Part AND Seconds\_Part COMPONENTS ARE TYPES AS Integer range 0 .. 59 RATHER THAN Natural range 0 .. 59 (WHICH IS PERFECTLY LEGAL) THE REASON IS MAINTAINABILITY AND READABILITY: WHAT IF THE SUBTYPE RANGE CHANGES OR DISAPPEARS ENTIRELY.

# DEFAULT VALUES

- DEFAULT VALUES MAY BE GIVEN IN THE TYPE DECLARATION FOR ALL OR SOME OF THE

## COMPONENTS

type Latitude\_Type is  
  record

    Degrees\_Part : Integer range -180 .. 180 := 0;  
    Minutes\_Part, Seconds\_Part : Integer range 0 .. 59 := 0;  
  end record;

- WHEN A RECORD OBJECT IS DECLARED, A COMPONENT AUTOMATICALLY RECEIVES A VALUE IF THE TYPE DECLARATION ASSIGNS A DEFAULT VALUE TO THAT COMPONENT.

FOR EXAMPLE:

    POSITION : Latitude\_Type;

CREATES:

    Position

0
0
0

-- Degrees\_Part

-- Minutes\_Part

-- Seconds\_Part

## INSTRUCTOR NOTES

YES, YOU MAY OVERRIDE THE DEFAULT.

POINT OUT THAT THE FOLLOWING REPRESENTATION IS ALSO POSSIBLE

```
type Position_Component_Type is (Degrees, Minutes, Seconds);  
type Latitude_Type is array (Position_Component_Type) of Integer;
```

BUT THAT IT IS LESS APPROPRIATE BECAUSE IT DOESN'T PROVIDE RANGE CHECKING FOR  
COMPONENT VALUES.

# INITIAL VALUE

- AS WITH ANY OBJECT DECLARATION, AN INITIAL VALUE MAY BE SPECIFIED

## CONTEXT:

```
type Latitude_Type is
record
  Degrees_Part      : Integer range -180 .. 180 := 0;
  Minutes_Part, Seconds_Part : Integer range 0 .. 59 := 0;
end record;
```

## EXAMPLE:

```
Position_1 : Latitude_Type := (90, 5, 1); -- has initial value (90, 5, 1)
```

```
Position_2 : Latitude_Type;           -- has initial value (0, 0, 0) by default
```

- THE INITIALIZATION VALUES IN THE OBJECT DECLARATION OVERRIDE THE DEFAULT VALUES OF THE TYPE DECLARATION.

**INSTRUCTOR NOTES**

THE FORMS FOR WRITING AN AGGREGATE ARE SPECIFIED ON THIS AND THE NEXT FOIL.

NOTE THAT THERE IS NO CHANCE FOR ERROR WHEN EACH COMPONENT IS NAMED.

# RECORD AGGREGATES

- AN AGGREGATE IS USED TO SPECIFY VALUES FOR A WHOLE RECORD.

## CONTEXT:

```
type Am_or_Pm_Type is (am, pm);
type Clock_Time_Type is
  record
    Hour      : Integer range 1 .. 12;
    Minute    : Integer range 0 .. 59;
    Second    : Integer range 0 .. 59;
    Am_or_Pm  : Am_or_Pm_Type;
  end record;
```

```
It_is : Clock_Time_Type;
```

- POSITIONAL FORM --- LIST IN ORDER  

```
if It_Is = (12, 20, 45, am) then
  Run_Batch;
end if;
```
- NAMED FORM --- MAY BE IN ANY ORDER  

```
if It_Is = (Am_or_Pm => am, Hour => 12, Minute => 20, Second => 45) then
  Run_Batch;
end if;
```



INSTRUCTOR NOTES

THE TWO NOTATIONS CAN BE MIXED, WITH CERTAIN RESTRICTIONS (AS NOTED ON THE FOIL).

POINT OUT THAT THIS IS NOT THE CASE WITH ARRAY AGGREGATES, WHICH MUST BE EITHER ALL POSITIONAL OR ALL NAMED.

# RECORD AGGREGATES

• MIXED POSITIONAL AND NAMED --- POSITIONAL MUST COME FIRST AND IN ORDER

## CONTEXT:

```
type Queue_Type is (Large, User, Graphics, Laser_Printer);
type Process_Descriptor_Type is
record
    Queue           : Queue_Type;
    ID_Number       : Integer range 1 .. 1_000_000;
    Process_Name    : String (1 .. 15);
    Owner_Name      : String (1 .. 12);
end record;
```

Process\_A : Process\_Descriptor\_Type;

## EXAMPLE:

```
if Process_A = (Laser_Printer, 987654, Owner_Name => "ASMITH",
                 Process_Name => "SOURCE LISTING") then
    .
    .
    .
end if;
```

## INSTRUCTOR NOTES

### POINT OUT THAT

(6, others => 2) IS WRONG BECAUSE REMAINING COMPONENTS ARE OF DIFFERENT TYPES.

(others => 50, Move) IS WRONG BECAUSE others MUST COME LAST.

(Op => Move, others => 50) IS LEGAL BECAUSE TYPES OF REMAINING COMPONENTS ARE ALL  
SUBTYPES OF Float

# RECORD AGGREGATES

others IS RARELY USEFUL FOR RECORDS AS COMPONENTS USUALLY ARE OF DIFFERENT

TYPES:

CONTEXT:

type Graphics\_Op\_Type is (Move, Line, Polygon);

type Instruction\_Type is  
record

Op : Graphics\_Op\_Type;

X\_Coord : Integer range 0 .. 319;

Y\_Coord : Integer range 0 .. 239;

end record;

Next\_Instruction : Instruction\_Type;

EXAMPLE:

(6, others => 2)

-- \*\* ILLEGAL

(others => 50, Move)

-- \*\* ILLEGAL

(Op => Move, others => 50)

-- LEGAL

INSTRUCTOR NOTES

THE AGGREGATE MUST CONTAIN A VALUE FOR EACH AND EVERY COMPONENT.

# RECORD AGGREGATES

- AN AGGREGATE MUST BE COMPLETE EVEN IF IT SUPPLIES THE SAME VALUES AS THE DEFAULT VALUES FOR SOME COMPONENTS.

CONTEXT:

```
type Latitude_Type is
  record
    Degrees_Part : Integer range -180 .. 180 := 0;
    Minutes_Part : Integer range 0 .. 59 := 0;
    Seconds_Part : Integer range 0 .. 59 := 0;
  end record;
```

EXAMPLE:

```
Old_Latitude : Latitude_Type := (30, 0, 0);    -- legal
New_Latitude : Latitude_Type := (30, 0, 0);    -- **ILLEGAL
```

INSTRUCTOR NOTES

A SPECIAL CASE.

THE REASON FOR EMBEDDING A COUNTER IN A RECORD IS TO GUARANTEE THAT ANY Counter\_Type VARIABLE DECLARED ALWAYS HAS A DEFAULT INITIAL VALUE, IN THIS CASE, 0. THIS IS THE CLOSEST MECHANISM TO AUTOMATIC INITIALIZATION IN Ada.

# RECORD AGGREGATE

- A ONE-COMPONENT AGGREGATE MUST BE IN NAMED NOTATION:

```
CONTEXT:
  type Counter_Type is
    record
      Value : Integer := 0;
    end record;
```

## EXAMPLES:

```
Counter : Counter_Type := (1);
Counter : Counter_Type := (value => 10);
Counter : Counter_Type ;
-- **ILLEGAL
-- legal
-- legal; Counter.Value has default
-- initial value of 0
```



INSTRUCTOR NOTES

IN CASE SOMEONE WONDERS HOW (3, 2, 1934) COULD BE FEBRUARY 3, TELL HIM/HER THAT'S HOW  
MOST OF THE WORLD WOULD READ IT.

# NAMED NOTATION SHOULD NORMALLY BE USED

- EASIER TO READ
- IT'S TOO EASY TO WRITE THINGS IN THE WRONG ORDER

## CONTEXT:

```
type Date_Type is
  record
    Month_Part : Integer range 1 .. 12;
    Day_Part   : Integer range 1 .. 31;
    Year_Part  : Integer range 1900 .. 2100;
  end record;
Due_Date : Date_Type;
```

## EXAMPLE:

```
Due_Date := (3, 2, 1934)      -- FEBRUARY 3, 1934
                        -- OR MARCH 2, 1934 ??
```

# INSTRUCTOR NOTES

## SOLUTION:

```
type Longitude_Type is
record
  Degrees_Part : Integer range -180 .. 180 := 0;
  Minutes_Part, Seconds_Part : Integer range 0 ..59 := 0;
end record;

type Global_Position_Type is
record
  Latitude_Part : Latitude_Type;
  Longitude_Part : Longitude_Type;
end record

POSITION: Global_Position_Type := ((90, 30, 5), (-10, 5, 5));
      (Other variations are possible)
```

BONUS POINT ANSWER - ??

# EXERCISE

- GIVEN THE FOLLOWING TYPE DEFINITION:

```
type Latitude_Type is
record
    Degrees_Part : Integer range -180 .. 180 := 0;
    Minutes_Part, Seconds_Part : Integer range 0 ..59 := 0;
end record;
```

DEFINE A Longitude Type (SIMILAR TO THE ABOVE) AND A Global\_Position\_Type, WHERE A GLOBAL POSITION CONSISTS OF A LATITUDE AND A LONGITUDE.

- PROVIDE AN AGGREGATE THAT WOULD ASSIGN THE FOLLOWING VALUES TO AN OBJECT OF TYPE Global\_Position\_Type;

```
Latitude : 90 degrees, 30 minutes, 5 seconds
Longitude : -10 degrees, 5 minutes, 5 seconds
```

(BONUS POINT TO ANYONE WHO CAN GUESS WHERE ON THE GLOBE THAT MIGHT BE.)

# INSTRUCTOR NOTES

THESE OPERATORS MAY BE USED ON THE RECORD ITSELF OR ON COMPONENTS OF THE RECORD.

NOTE THAT WITHOUT THE QUADRANT COMPONENT, TYPE `Vertex_Type` MIGHT BE IMPLEMENTED AS AN ARRAY TYPE, SINCE BOTH COMPONENTS WOULD THEN BE OF TYPE `Float`.

# RECORD OPERATIONS - EQUALITY/INEQUALITY

## EQUALITY/INEQUALITY

- WHOLE RECORDS
- COMPONENTS OF RECORDS

### CONTEXT:

```
type Vertex_Type is
record
    X_Part, Y_Part : Float;
    Quadrant : Integer range 1 .. 4;
end record;

Vertex_1, Vertex_2 : Vertex_Type;
```

### EXAMPLE:

```
if Vertex_1 = Vertex_2 then
    ...
end if;

or

if Vertex_1.X_Part > 12.0 then
    ...
end if;
```

**INSTRUCTOR NOTES**

**YOU CAN ASSIGN TO WHOLE RECORDS OR INDIVIDUAL RECORD COMPONENTS.**

# RECORD OPERATIONS - ASSIGNMENT

- WHOLE RECORD ASSIGNMENT
- ASSIGNMENT TO INDIVIDUAL COMPONENTS

CONTEXT:

```
type Vertex_Type is
  record
    X_Part, Y_Part : Float;
    Quadrant : Integer range 1 .. 4;
  end record;
Vertex_1 : Vertex_Type;
```

EXAMPLES:

```
Vertex_1 := (1.0, 3.3, 1);      -- WHOLE RECORD
Vertex_1.Y_Part := 10.5;       -- INDIVIDUAL COMPONENT
```



INSTRUCTOR NOTES

THESE OPERATIONS MAY NOT BE PERFORMED ON AN ENTIRE RECORD.

# **RECORD OPERATIONS - RELATIONAL, LOGICAL, AND ARITHMETIC**

- PERFORMED ON INDIVIDUAL COMPONENTS AND NOT ON THE WHOLE RECORD (E.G. YOU CANNOT ADD Buffer\_Type OBJECTS)
- THE OPERATION MUST BE COMPATIBLE WITH THE TYPE OF THE COMPONENT

INSTRUCTOR NOTES

WHAT ABOUT ATTRIBUTES?

# ATTRIBUTES

- ATTRIBUTES MAY BE APPLIED TO SELECTED COMPONENTS
- ATTRIBUTES MUST BE COMPATIBLE WITH SELECTED COMPONENTS

INSTRUCTOR NOTES

o RESTATE THAT AN ARRAY OBJECT WITH A SUBSCRIPT IS ESSENTIALLY THE COMPONENT VARIABLE.

TRACE THROUGH THE STATEMENTS BY FILLING IN THE PICTURE ON THE BOARD.

# ARRAYS OF RECORDS

## CONTEXT:

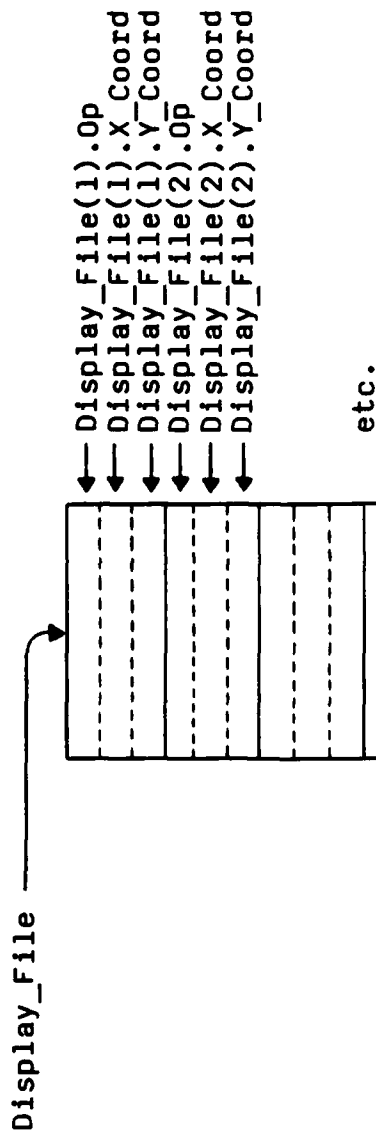
```

type Graphics_Op_Type is (Move, Line, Polygon);

type Instruction_Type is
  record
    Op : Graphics_Op_Type;
    X_Coord : Integer range 0 .. 319;
    Y_Coord : Integer range 0 .. 239;
  end record;

type Display_File_Type is array (1 .. 500) of Instruction_Type;
Display_File : Display_File_Type;
  
```

## STRUCTURE:



INSTRUCTOR NOTES

STEP THROUGH EACH EXAMPLE.

## ARRAYS OF RECORDS

```
Display_File (1) := (Op      => Line,  
                     X_Coord => 10, Y_Coord => 50);
```

```
Display_File (2) := Display_File(1);
```

```
Display_File (3 .. 4) := Display_File (1 .. 2);
```

```
case Display_File(2).Op is  
  when Move =>  
    ...  
  when Line =>  
    ...  
  when others =>  
    ...  
end case;
```



INSTRUCTOR NOTES

ASK THE CLASS HOW THEY WOULD DO I/O FOR RECORDS.

THEY WOULD HAVE TO DO IT BY COMPONENTS.

THEY WILL SEE IN SECTION 13 THAT THERE IS SOMETHING CALLED Direct\_IO AND Sequential\_IO.  
THESE WOULD BE USED TO DO I/O FOR RECORDS.

ASSIGN EXERCISES 22 THROUGH 24 OF THE EXERCISE BOOKLET FOR LAB WORK. STRESS EXERCISE 24.

ASSIGN CHAPTER 9 OF THE PRIMER.

## I/O FOR RECORD TYPES

- NONE IS PREDEFINED
- MUST DO COMPONENT BY COMPONENT  
FOR Text\_10;

INSTRUCTOR NOTES

VG 728.2

9-251

123 577 584 590 596 602 608 614 620 626 632 638 644 650 656 662 668 674 680 686 692 698 704 710 716 722 728 734 740 746 752 758 764 770 776 782 788 794 800 806 812 818 824 830 836 842 848 854 860 866 872 878 884 890 896 902 908 914 920 926 932 938 944 950 956 962 968 974 980 986 992 998 1004 1010 1016 1022 1028 1034 1040 1046 1052 1058 1064 1070 1076 1082 1088 1094 1100 1106 1112 1118 1124 1130 1136 1142 1148 1154 1160 1166 1172 1178 1184 1190 1196 1202 1208 1214 1220 1226 1232 1238 1244 1250 1256 1262 1268 1274 1280 1286 1292 1298 1304 1310 1316 1322 1328 1334 1340 1346 1352 1358 1364 1370 1376 1382 1388 1394 1400 1406 1412 1418 1424 1430 1436 1442 1448 1454 1460 1466 1472 1478 1484 1490 1496 1502 1508 1514 1520 1526 1532 1538 1544 1550 1556 1562 1568 1574 1580 1586 1592 1598 1604 1610 1616 1622 1628 1634 1640 1646 1652 1658 1664 1670 1676 1682 1688 1694 1700 1706 1712 1718 1724 1730 1736 1742 1748 1754 1760 1766 1772 1778 1784 1790 1796 1802 1808 1814 1820 1826 1832 1838 1844 1850 1856 1862 1868 1874 1880 1886 1892 1898 1904 1910 1916 1922 1928 1934 1940 1946 1952 1958 1964 1970 1976 1982 1988 1994 2000 2006 2012 2018 2024 2030 2036 2042 2048 2054 2060 2066 2072 2078 2084 2090 2096 2102 2108 2114 2120 2126 2132 2138 2144 2150 2156 2162 2168 2174 2180 2186 2192 2198 2204 2210 2216 2222 2228 2234 2240 2246 2252 2258 2264 2270 2276 2282 2288 2294 2300 2306 2312 2318 2324 2330 2336 2342 2348 2354 2360 2366 2372 2378 2384 2390 2396 2402 2408 2414 2420 2426 2432 2438 2444 2450 2456 2462 2468 2474 2480 2486 2492 2498 2504 2510 2516 2522 2528 2534 2540 2546 2552 2558 2564 2570 2576 2582 2588 2594 2600 2606 2612 2618 2624 2630 2636 2642 2648 2654 2660 2666 2672 2678 2684 2690 2696 2702 2708 2714 2720 2726 2732 2738 2744 2750 2756 2762 2768 2774 2780 2786 2792 2798 2804 2810 2816 2822 2828 2834 2840 2846 2852 2858 2864 2870 2876 2882 2888 2894 2900 2906 2912 2918 2924 2930 2936 2942 2948 2954 2960 2966 2972 2978 2984 2990 2996 3002 3008 3014 3020 3026 3032 3038 3044 3050 3056 3062 3068 3074 3080 3086 3092 3098 3104 3110 3116 3122 3128 3134 3140 3146 3152 3158 3164 3170 3176 3182 3188 3194 3200 3206 3212 3218 3224 3230 3236 3242 3248 3254 3260 3266 3272 3278 3284 3290 3296 3302 3308 3314 3320 3326 3332 3338 3344 3350 3356 3362 3368 3374 3380 3386 3392 3398 3404 3410 3416 3422 3428 3434 3440 3446 3452 3458 3464 3470 3476 3482 3488 3494 3500 3506 3512 3518 3524 3530 3536 3542 3548 3554 3560 3566 3572 3578 3584 3590 3596 3602 3608 3614 3620 3626 3632 3638 3644 3650 3656 3662 3668 3674 3680 3686 3692 3698 3704 3710 3716 3722 3728 3734 3740 3746 3752 3758 3764 3770 3776 3782 3788 3794 3800 3806 3812 3818 3824 3830 3836 3842 3848 3854 3860 3866 3872 3878 3884 3890 3896 3902 3908 3914 3920 3926 3932 3938 3944 3950 3956 3962 3968 3974 3980 3986 3992 3998 4004 4010 4016 4022 4028 4034 4040 4046 4052 4058 4064 4070 4076 4082 4088 4094 4100 4106 4112 4118 4124 4130 4136 4142 4148 4154 4160 4166 4172 4178 4184 4190 4196 4202 4208 4214 4220 4226 4232 4238 4244 4250 4256 4262 4268 4274 4280 4286 4292 4298 4304 4310 4316 4322 4328 4334 4340 4346 4352 4358 4364 4370 4376 4382 4388 4394 4400 4406 4412 4418 4424 4430 4436 4442 4448 4454 4460 4466 4472 4478 4484 4490 4496 4502 4508 4514 4520 4526 4532 4538 4544 4550 4556 4562 4568 4574 4580 4586 4592 4598 4604 4610 4616 4622 4628 4634 4640 4646 4652 4658 4664 4670 4676 4682 4688 4694 4700 4706 4712 4718 4724 4730 4736 4742 4748 4754 4760 4766 4772 4778 4784 4790 4796 4802 4808 4814 4820 4826 4832 4838 4844 4850 4856 4862 4868 4874 4880 4886 4892 4898 4904 4910 4916 4922 4928 4934 4940 4946 4952 4958 4964 4970 4976 4982 4988 4994 5000 5006 5012 5018 5024 5030 5036 5042 5048 5054 5060 5066 5072 5078 5084 5090 5096 5102 5108 5114 5120 5126 5132 5138 5144 5150 5156 5162 5168 5174 5180 5186 5192 5198 5204 5210 5216 5222 5228 5234 5240 5246 5252 5258 5264 5270 5276 5282 5288 5294 5300 5306 5312 5318 5324 5330 5336 5342 5348 5354 5360 5366 5372 5378 5384 5390 5396 5402 5408 5414 5420 5426 5432 5438 5444 5450 5456 5462 5468 5474 5480 5486 5492 5498 5504 5510 5516 5522 5528 5534 5540 5546 5552 5558 5564 5570 5576 5582 5588 5594 5600 5606 5612 5618 5624 5630 5636 5642 5648 5654 5660 5666 5672 5678 5684 5690 5696 5702 5708 5714 5720 5726 5732 5738 5744 5750 5756 5762 5768 5774 5780 5786 5792 5798 5804 5810 5816 5822 5828 5834 5840 5846 5852 5858 5864 5870 5876 5882 5888 5894 5900 5906 5912 5918 5924 5930 5936 5942 5948 5954 5960 5966 5972 5978 5984 5990 5996 6002 6008 6014 6020 6026 6032 6038 6044 6050 6056 6062 6068 6074 6080 6086 6092 6098 6104 6110 6116 6122 6128 6134 6140 6146 6152 6158 6164 6170 6176 6182 6188 6194 6200 6206 6212 6218 6224 6230 6236 6242 6248 6254 6260 6266 6272 6278 6284 6290 6296 6302 6308 6314 6320 6326 6332 6338 6344 6350 6356 6362 6368 6374 6380 6386 6392 6398 6404 6410 6416 6422 6428 6434 6440 6446 6452 6458 6464 6470 6476 6482 6488 6494 6500 6506 6512 6518 6524 6530 6536 6542 6548 6554 6560 6566 6572 6578 6584 6590 6596 6602 6608 6614 6620 6626 6632 6638 6644 6650 6656 6662 6668 6674 6680 6686 6692 6698 6704 6710 6716 6722 6728 6734 6740 6746 6752 6758 6764 6770 6776 6782 6788 6794 6800 6806 6812 6818 6824 6830 6836 6842 6848 6854 6860 6866 6872 6878 6884 6890 6896 6902 6908 6914 6920 6926 6932 6938 6944 6950 6956 6962 6968 6974 6980 6986 6992 6998 7004 7010 7016 7022 7028 7034 7040 7046 7052 7058 7064 7070 7076 7082 7088 7094 7100 7106 7112 7118 7124 7130 7136 7142 7148 7154 7160 7166 7172 7178 7184 7190 7196 7202 7208 7214 7220 7226 7232 7238 7244 7250 7256 7262 7268 7274 7280 7286 7292 7298 7304 7310 7316 7322 7328 7334 7340 7346 7352 7358 7364 7370 7376 7382 7388 7394 7400 7406 7412 7418 7424 7430 7436 7442 7448 7454 7460 7466 7472 7478 7484 7490 7496 7502 7508 7514 7520 7526 7532 7538 7544 7550 7556 7562 7568 7574 7580 7586 7592 7598 7604 7610 7616 7622 7628 7634 7640 7646 7652 7658 7664 7670 7676 7682 7688 7694 7700 7706 7712 7718 7724 7730 7736 7742 7748 7754 7760 7766 7772 7778 7784 7790 7796 7802 7808 7814 7820 7826 7832 7838 7844 7850 7856 7862 7868 7874 7880 7886 7892 7898 7904 7910 7916 7922 7928 7934 7940 7946 7952 7958 7964 7970 7976 7982 7988 7994 8000 8006 8012 8018 8024 8030 8036 8042 8048 8054 8060 8066 8072 8078 8084 8090 8096 8102 8108 8114 8120 8126 8132 8138 8144 8150 8156 8162 8168 8174 8180 8186 8192 8198 8204 8210 8216 8222 8228 8234 8240 8246 8252 8258 8264 8270 8276 8282 8288 8294 8300 8306 8312 8318 8324 8330 8336 8342 8348 8354 8360 8366 8372 8378 8384 8390 8396 8402 8408 8414 8420 8426 8432 8438 8444 8450 8456 8462 8468 8474 8480 8486 8492 8498 8504 8510 8516 8522 8528 8534 8540 8546 8552 8558 8564 8570 8576 8582 8588 8594 8600 8606 8612 8618 8624 8630 8636 8642 8648 8654 8660 8666 8672 8678 8684 8690 8696 8702 8708 8714 8720 8726 8732 8738 8744 8750 8756 8762 8768 8774 8780 8786 8792 8798 8804 8810 8816 8822 8828 8834 8840 8846 8852 8858 8864 8870 8876 8882 8888 8894 8900 8906 8912 8918 8924 8930 8936 8942 8948 8954 8960 8966 8972 8978 8984 8990 8996 9002 9008 9014 9020 9026 9032 9038 9044 9050 9056 9062 9068 9074 9080 9086 9092 9098 9104 9110 9116 9122 9128 9134 9140 9146 9152 9158 9164 9170 9176 9182 9188 9194 9200 9206 9212 9218 9224 9230 9236 9242 9248 9254 9260 9266 9272 9278 9284 9290 9296 9302 9308 9314 9320 9326 9332 9338 9344 9350 9356 9362 9368 9374 9380 9386 9392 9398 9404 9410 9416 9422 9428 9434 9440 9446 9452 9458 9464 9470 9476 9482 9488 9494 9500 9506 9512 9518 9524 9530 9536 9542 9548 9554 9560 9566 9572 9578 9584 9590 9596 9602 9608 9614 9620 9626 9632 9638 9644 9650 9656 9662 9668 9674 9680 9686 9692 9698 9704 9710 9716 9722 9728 9734 9740 9746 9752 9758 9764 9770 9776 9782 9788 9794 9800 9806 9812 9818 9824 9830 9836 9842 9848 9854 9860 9866 9872 9878 9884 9890 9896 9902 9908 9914 9920 9926 9932 9938 9944 9950 9956 9962 9968 9974 9980 9986 9992 9998 10004 10010 10016 10022 10028 10034 10040 10046 10052 10058 10064 10070 10076 10082 10088 10094 10100 10106 10112 10118 10124 10130 10136 10142 10148 10154 10160 10166 10172 10178 10184 10190 10196 10202 10208 10214 10220 10226 10232 10238 10244 10250 10256 10262 10268 10274 10280 10286 10292 10298 10304 10310 10316 10322 10328 10334 10340 10346 10352 10358 10364 10370 10376 10382 10388 10394 10400 10406 10412 10418 10424 10430 10436 10442 10448 10454 10460 10466 10472 10478 10484 10490 10496 10502 10508 10514 10520 10526 10532 10538 10544 10550 10556 10562 10568 10574 10580 10586 10592 10598 10604 10610 10616 10622 10628 10634 10640 10646 10652 10658 10664 10670 10676 10682 10688 10694 10700 10706 10712 10718 10724 10730 10736 10742 10748 10754 10760 10766 10772 10778 10784 10790 10796 10802 10808 10814 10820 10826 10832 10838 10844 10850 10856 10862 10868 10874 10880 10886 10892 10898 10904 10910 10916 10922 10928 10934 10940 10946 10952 10958 10964 10970 10976 10982 10988 10994 11000 11006 11012 11018 11024 11030 11036 11042 11048 11054 11060 11066 11072 11078 11084 11090 11096 11102 11108 11114 11120 11126 11132 11138 11144 11150 11156 11162 11168 11174 11180 11186 11192 11198 11204 11210 11216 11222 11228 11234 11240 11246 11252 11258 11264 11270 11276 11282 11288 11294 11300 11306 11312 11318 11324 11330 11336 11342 11348 11354 11360 11366 11372 11378 11384 11390 11396 11402 11408 11414 11420 11426 11432 11438 11444 11450 11456 11462 11468 11474 11480 11486 11492 11498 11504 11510 11516 11522 11528 11534 11540 11546 11552 11558 11564 11570 11576 11582 11588 11594 11600 11606 11612 11618 11624 11630 11636 11642 11648 11654 11660 11666 11672 11678 11684 11690 11696 11702 11708 11714 11720 11726 11732 11738 11744 11750 11756 11762 11768 11774 11780 11786 11792 11798 11804 11810 11816 11822 11828 11834 11840 11846 11852 11858 11864 11870 11876 11882 11888 11894 11900 11906 11912 11918 11924 11930 11936 11942 11948 11954 11960 11966 11972 11978 11984 11990 11996 12002 12008 12014 12020 12026 12032 12038 12044 12050 12056 12062 12068 12074 12080 12086 12092 12098 12104 12110 12116 12122 12128 12134 12140 12146 12152 12158 12164 12170 12176 12182 12188 12194 12200 12206 12212 12218 12224 12230 12236 12242 12248 12254 12260 12266 12272 12278 12284 12290 12296 12302 12308 12314 12320 12326 12332 12338 12344 12350 12356 12362 12368 12374 12380 12386 12392 12398 12404 12410 12416 12422 12428 12434 12440 12446 12452 12458 12464 12470 12476 12482 12488 12494 12500 12506 12512 12518 12524 12530 12536 12542 12548 12554 12560 12566 12572 12578 12584 12590 12596 12602 12608 12614 12620 12626 12632 12638 12644 12650 12656 12662 12668 12674 12680 12686 12692 12698 12704 12710 12716 12722 12728 12734 12740 12746 12752 12758 12764 12770 12776 12782 12788 12794 12800 12806 12812 12818 12824 12830 12836 12842 12848 12854 12860 12866 12872 12878 12884 12890 12896 12902 12908 12914 12920 12926 12932 12938 12944 12950 12956 12962 12968 12974 12980 12986 12992 12998 13004 13010 13016 13022 13028 13034 13040 13046 13052 13058 13064 13070 13076 13082 13088 13094 13100 13106 13112 13118 13124 13130 13136 13142 13148 13154 13160 13166 13172 13178 13184 13190 13196 13202 13208 13214 13220 13226 13232 13238 13244 13250 13256 13262 13268 13274 13280 13286 13292 13298 13304 13310 13316 13322 13328 13334 13340 13346 13352 13358 13364 13370 13376 13382 13388 13394 13400 13406 13412 13418 13424 13430 13436 13442 13448 13454 13460 13466 13472 13478 13484 13490 13496 13502 13508 13514 13520 13526 13532 13538 13544 13550 13556 13562 13568 13574 13580 13586 13592 13598 13604 13610 13616 13622 13628 13634 13640 13646 13652 13658 13664 13670 13676 13682 13688 13694 13700 13706 13712 13718 13724 13730 13736 13742 13748 13754 13760 13766 13772 13778 13784 13790 13796 13802 13808 13814 13820 13826 13832 13838 13844 13850 13856 13862 13868 13874 13880 13886 13892 13898 13904 13910 13916 13922 13928 13934 13940 13946 13952 13958 13964 13970 13976 13982 13988 13994 14000 14006 14012 14018 14024 14030 14036 14042 14048 14054 14060 14066 14072 14078 14084 14090 14096 14102 14108 14114 14120 14126 14132 14138 14144 14150 14156 14162 14168 14174 14180 14186 14192 14198 14204 14210 14216 14222 14228 14234 14240 14246 14252 14258 14264 14270 14276 14282 14288 14294 14300 14306 14312 14318 14324 14330 14336 14342 14348 14354 14360 14366 14372 14378 14384 14390 14396 14402 14408 14414 14420 14426 14432 14438 14444 14450 1

# RECORD TYPES WITH DISCRIMINANTS

VG 728.2

9-25

## INSTRUCTOR NOTES

- THIS SLIDE AND THE NEXT THREE INTRODUCE THE NEED FOR DISCRIMINANTS
- THIS SLIDE DESCRIBES A VARYING LENGTH STRING TYPE WITH A FIXED MINIMUM LENGTH.  
THE NEXT SLIDE INTRODUCES THE NEED FOR THE MAXIMUM LENGTH TO BE A DISCRIMINANT.
- DO NOT GO INTO DETAIL ABOUT VARYING LENGTH STRINGS.
- BULLET #2
  - TELL THE CLASS THAT THIS COULD BE HANDLED BY DEFINING String40\_Type, String256\_Type, String500\_Type, ETC. EACH OF THESE TYPES IS JUST A COPY OF String80 WITH BOTH OCCURRENCES OF 80 REPLACED BY THE REQUIRED MAXIMUM LENGTH.
  - NOTE THAT THIS IS WASTED EFFORT
  - USES SEVERAL TYPE DEFINITIONS WHERE IDEALLY, ONE WOULD BE BETTER
  - USING THE LARGEST OF THE MAXIMUM LENGTHS, SAY 500, WOULD BE WASTEFUL WHEN A MAXIMUM OF LENGTH 16 IS NEEDED
- BULLET #3
  - THE PLOT THICKENS.

# WHY DO WE NEED DISCRIMINANTS?

- SUPPOSE WE NEED A VARYING LENGTH STRING RATHER THAN A FIXED STRING
  - MUST BE CAPABLE OF HOLDING ALL STRINGS UP TO SOME MAXIMUM LENGTH
  - SUPPOSE THE MAXIMUM LENGTH IS 80

```
type String80_Type is
record
    Contents      : String (1 .. 80);
    Current_Length : Natural;
end record;
```

- GIVEN THE DECLARATION  
String80 : String80\_Type;  
THE CURRENT STRING VALUE IS  
String80.Contents (1 .. String80.Current\_Length)  
TO ASSIGN THE STRING "Ada" OF LENGTH 3 TO String80, WE NEED THE TWO  
ASSIGNMENTS

```
String80.Current_Length := 3;
String80.Contents (1 .. 3) := "Ada";
```

- SUPPOSE WE ALSO NEED VARYING STRINGS WITH MAXIMUM LENGTHS 40, 256, 500, 16,  
ETC.
- WHAT IF THE MAXIMUM LENGTH IS NOT KNOWN UNTIL PROGRAM EXECUTION?

## INSTRUCTOR NOTES

- DETAILS PROVIDED IN THE REMAINDER OF THIS SECTION.

## WHY DO WE NEED DISCRIMINANTS? - Continued

- WE SHOULD LIKE TO DEFINE ONE VARYING STRING TYPE WITH THE MAXIMUM LENGTH LEFT BLANK. THE BLANK WOULD BE FILLED IN WHEN A VARYING STRING OBJECT IS DECLARED.

```
type Varying_String_Type ( MAXIMUM LENGTH ) is
record
  Contents      : String (1 .. MAXIMUM LENGTH );
  Current_Length : Natural;
end record;
```

```
String80 : Varying_String_Type (80);
String16 : Varying_String_Type (16);

procedure Example (Name_Length:Natural) is
  Temp : Varying_String_Type (Name_Length);
begin
  ...
end Example;
```

- THIS CAN BE ACCOMPLISHED WITH DISCRIMINANTS.



## INSTRUCTOR NOTES

- THIS SLIDE ILLUSTRATES THE NEED FOR VARIANTS
- BULLET #3
  - LET THE CLASS TAKE A CRACK AT IT FIRST
  - PARTIAL LIST OF PROBLEMS
    - NOT CLEAR THAT Customer\_Number\_Part AND Order\_Size\_Part ARE VALID ONLY WHEN Variety\_Part = Order\_Transaction. SIMILARLY FOR Shipment\_Size\_Part
    - POSSIBLE TO ACCIDENTALLY USE Order\_Size\_Part WHEN Variety\_Part = Items\_Received\_Transaction
    - POSSIBLE TO LEAVE OBJECT IN AN INCONSISTENT STATE BY CHANGING Variety\_Part WITHOUT CHANGING APPROPRIATE COMPONENTS
    - STORAGE WASTED: Shipment\_Size\_Part NOT NEEDED WHEN Variety\_Part = Order\_Transaction. (IN CASE ANYONE SUGGESTS COMBINING Order\_Size\_Part AND Shipment\_Size\_Part INTO ONE COMPONENT THIS WOULD SAVE SPACE BUT MAKES THE USE OF THE RECORD TYPE MORE DIFFICULT TO UNDERSTAND)
  - VARIANTS TO THE RESCUE ON THE NEXT SLIDE

## ANOTHER EXAMPLE

- IN AN INVENTORY SYSTEM WE MIGHT HAVE ORDER TRANSACTIONS AND ITEMS RECEIVED TRANSACTIONS.
  - FOR EACH TRANSACTION WE NEED
    - TIME OF THE TRANSACTION
    - UNIQUE TRANSACTION NUMBER
  - FOR ORDER TRANSACTIONS WE NEED
    - CUSTOMER NUMBER
    - SIZE OF THE ORDER
  - FOR ITEMS RECEIVED TRANSACTIONS WE NEED
    - SIZE OF THE SHIPMENT
- THIS COULD BE MODELLED AS A RECORD TYPE
 

```

type Transaction_Variety_Type is (Order_Transaction, Items_Received_Transaction);

type Transaction_Type is
  record
    Variety_Part : Transaction_Variety_Type;
    Time_Part   : Calendar.Time;
    Number_Part : Positive
    Customer_Number_Part : Customer_Number_Type;
    Order_Size_Part   : Item_Count_Type;
    Shipment_Size_Part : Item_Count_Type;
  end record;
      
```

THIS IS CORRECT Ada AND WORKS.
- WHAT'S "WRONG" WITH THIS APPROACH?

# INSTRUCTOR NOTES

- DETAILS PROVIDED LATER IN THIS SECTION.
- AVOID THE TERM VARIANTS.

## EXAMPLE TWO (Continued)

- WE WOULD LIKE A WAY TO INDICATE THAT THE EXISTENCE OF CERTAIN COMPONENTS DEPENDS ON THE TRANSACTION
    - FOR Order\_Transactions WE WANT Transaction\_Type TO BE DEFINED AS
- ```

type Transaction_Type is
  record
    Variety_Part      : Transaction_Variety_Type; -- Always Order_Transaction
    Time_Part         : Calendar.Time;
    Number_Part       : Positive;
    Customer_Number_Part : Customer_Number_Type;
    Order_Size_Part   : Item_Count_Type;
  end record;

```
- FOR Items\_Received\_Transaction WE WANT Transaction\_Type TO BE DEFINED AS
- ```

type Transaction_Type is
  record
    Variety_Part      : Transaction_Variety_Type; -- Always Items_Received_Transaction
    Time_Part         : Calendar.Time;
    Number_Part       : Positive;
    Shipment_Size_Part : Item_Count_Type;
  end record;

```
- THIS CAN BE ACCOMPLISHED THROUGH THE USE OF DISCRIMINANTS

## INSTRUCTOR NOTES

- BULLET #3

- GIVE THE CLASS SOME EXAMPLES THEY WILL RUN INTO LATER IN THIS SECTION
  - AS AN EXAMPLE OF A RECORD TYPE FOR WHICH OBJECTS IN THE TYPE CONTAIN ARRAYS WITH DIFFERENT BOUNDS, WE WILL HAVE AN EXAMPLE OF A VARYING LENGTH STRING, WHERE THE DISCRIMINANT SPECIFIES THE MAXIMUM SIZE STRING THE OBJECT SHOULD HOLD.
  - AS AN EXAMPLE OF A RECORD TYPE FOR WHICH OBJECTS IN THE TYPE MAY HAVE DIFFERENT COMPONENTS, WE HAVE A SENSOR READING TYPE. OBJECTS IN THIS TYPE WILL CONTAIN A FLAG INDICATING WHETHER OR NOT A VALID SENSOR READING WAS OBTAINED. IF THE FLAG INDICATES A VALID READING THEN THE OBJECT WILL ALSO CONTAIN THE READING; OTHERWISE THE OBJECT ONLY CONTAINS THE FLAG.

- BULLET #4

- EMPHASIZE THE DISCRIMINANT AS A RECORD COMPONENT
- MENTION THAT THERE IS A RESTRICTION ON CHANGING THE VALUE OF A DISCRIMINANT, AS WILL BE SEEN LATER.

# DISCRIMINANTS

- RECORD TYPES MAY BE DECLARED WITH DISCRIMINANTS.
- DISCRIMINANTS ACT AS "PARAMETERS" TO RECORDS IN THE TYPE.
- DIFFERENT OBJECTS IN THE TYPE MAY HAVE DIFFERENT COMPONENTS, OR MAY CONTAIN ARRAYS WITH DIFFERENT BOUNDS, DEPENDING ON THE "PARAMETERS" SPECIFIED FOR EACH OBJECT.
- BESIDES ACTING AS A "PARAMETER," A DISCRIMINANT IS ALSO A COMPONENT OF THE RECORD.

# INSTRUCTOR NOTES

- POINT OUT THE TWO DISTINCT OCCURRENCES OF **DISCRIMINANT SPECIFICATION** IN THE EXAMPLE.
- DO NOT DISCUSS THE USE OF **DEFAULT INITIAL VALUE** NOW.

# DECLARING RECORD TYPES WITH DISCRIMINANTS

- TYPE DECLARATION

```
type TYPE NAME ( DISCRIMINANT SPECIFICATION { DISCRIMINANT SPECIFICATION } ) is  
  record  
  ... -- COMPONENT DECLARATIONS  
  end record;
```

- FORM OF A **DISCRIMINANT SPECIFICATION** :

```
IDENTIFIER { , IDENTIFIER } : DISCRETE TYPE NAME [ := DEFAULT INITIAL VALUE ]
```

- EXAMPLE

```
type Message_Type (Maximum_Length, Initial_Length : Integer := 0;  
  End_Character : Character := ',') is  
  record  
  ...  
  end record;
```



## INSTRUCTOR NOTES

- BULLET #2

- THE VALUES IN THE CONSTRAINT CAN BE EXPRESSIONS INVOLVING VARIABLES AND FUNCTION CALLS. FOR NOW MOSTLY CONTEND WITH EXPRESSIONS NOT INVOLVING VARIABLES OR FUNCTION CALLS. AT END OF SECTION WE WILL RETURN TO THIS.

# DISCRIMINANT CONSTRAINTS

- AN OBJECT DECLARATION FOR A TYPE WITH DISCRIMINANTS MAY CONTAIN A DISCRIMINANT CONSTRAINT.
- THE DISCRIMINANT CONSTRAINT SPECIFIES THE VALUES TO BE USED FOR THAT OBJECT'S "PARAMETERS".
- DISCRIMINANT CONSTRAINTS MAY BE NAMED, POSITIONAL, OR MIXED:  
  
NAMED:  
    Message : Message\_Type (Maximum\_Length => 10, End\_Character => '/',  
                              Initial\_Length => 5);  
  
POSITIONAL:  
    Message : Message\_Type (10, 5, '/');  
  
MIXED:  
    Message : Message\_Type (10, Initial\_Length => 5, End\_Character => '/');

## INSTRUCTOR NOTES

- SEVERAL EXAMPLES OF SUCH RECORD TYPES WILL APPEAR IN THIS SECTION.
- VARIANTS ALLOW US TO REFLECT THE LOGICAL STRUCTURE OF OUR DATA. THIS IS ILLUSTRATED WITH THE EXAMPLE ON THE NEXT PAGE.

# VARIANTS

- A RECORD TYPE WITH DISCRIMINANTS CAN HAVE DIFFERENT FORMS CALLED VARIANTS.
- WITHIN EACH VARIANT THERE ARE DIFFERENT RECORD COMPONENTS WITH DIFFERENT NAMES AND POSSIBLY DIFFERENT TYPES.
- THE VARIANT THAT AN OBJECT BELONGS TO IS DETERMINED BY THE VALUE OF ITS DISCRIMINANTS.

## INSTRUCTOR NOTES

- THESE TYPE DEFINITIONS MIGHT APPEAR AS PART OF AN INVENTORY CONTROL SYSTEM.
- Transaction\_Type REFLECTS TWO LOGICAL TRANSACTIONS: Order\_Transaction AND Items\_Received\_Transaction. BOTH TRANSACTIONS REQUIRE TIME AND PART NUMBER. AN Order\_Transaction MUST RECORD THE CUSTOMER PLACING THE ORDER AND THE SIZE OF THE ORDER, WHILE AN Items\_Received\_Transaction MUST RECORD THE SIZE OF THE SHIPMENT RECEIVED. USING Transaction\_Variety\_Type AS A DISCRIMINANT ALLOWS Transaction\_Type TO REFLECT BOTH LOGICAL VIEWS OF THE DATA.

# DECLARATIONS OF TYPES WITH VARIANTS - EXAMPLE

- DECLARATIONS:

```

type Transaction_Variety_Type is (Order_Transaction, Items_Received_Transaction);

type Transaction_Type (Variety : Transaction_Variety_Type) is
record
    Transaction_Time_Part : Calendar.Time;      -- Calendar is predefined package
    Transaction_Number_Part : Positive;
    case Variety is
        when Order_Transaction =>
            Customer_Number_Part : Customer_Number_Type;
            Order_Size_Part : Item_Count_Type;
        when Items_Received_Transaction =>
            Shipment_Size_Part : Item_Count_Type;
    end case;
end record;

```

- POSSIBLE FORMS OF TRANSACTION TYPE OBJECTS

Variety
Transaction_Time_Part
Transaction_Number_Part
Customer_Number_Part
Order_Size_Part

Variety = Order\_Transaction

Variety
Transaction_Time_Part
Transaction_Number_Part
Shipment_Size_Part

Variety = Items\_Received\_Transaction

INSTRUCTOR NOTES

- TAKE SOME TIME WITH THIS SLIDE. MAKE SURE THE CLASS UNDERSTANDS THE GENERAL FORM.

# DECLARATION OF TYPES WITH VARIANTS - GENERAL FORM

type **TYPE NAME** ( **DISCRIMINANT SPECIFICATION** { ; **DISCRIMINANT SPECIFICATION** } ) is  
record

**COMPONENT LIST**  
end record;

- THREE POSSIBLE FORMS OF **COMPONENT LIST** :

ORDINARY COMPONENT DECLARATION	VARIANT PART	null;
{ ORDINARY COMPONENT DECLARATION		
[ VARIANT PART ]		

- FORM OF A **VARIANT PART** :

case **DISCRIMINANT NAME** is  
when **CHOICE LIST** =>  
**COMPONENT LIST**  
{ when **CHOICE LIST** =>  
**COMPONENT LIST** }  
end case;

- FORM OF A **CHOICE LIST** :  
SAME AS FOR A CASE STATEMENT:  
**CHOICE** { | **CHOICE** }  
WHERE EACH **CHOICE** IS AN EXPRESSION OR A RANGE



## INSTRUCTOR NOTES

- EMPHASIZE HOW THIS TYPE REFLECTS THE LOGICAL STRUCTURE OF THE DATA.

## ANOTHER TYPE WITH VARIANTS

- A TYPE TO REPRESENT DATA PROVIDED BY A SENSOR.
- THE SENSOR HAS A BUILT-IN SELF-TEST MECHANISM, AND SETS A "VALIDITY BIT" WHEN THE SELF-TEST SUCCEEDS. IT ALSO PROVIDES DATA OF TYPE Integer THAT IS MEANINGFUL ONLY WHEN THE VALIDITY BIT IS ON.
- AN ITEM OF DATA IS EITHER VALID OR INVALID, AND ONLY VALID ITEMS HAVE INTEGER VALUES ASSOCIATED WITH THEM.

```
type Sensor_Reading_Type (Valid : Boolean := False) is
  record
    case Valid is
      when True =>
        Reading_Part : Integer;
      when False =>
        null;
    end case;
  end record;
```

INSTRUCTOR NOTES

- THE NEXT THREE SLIDES GIVES EXAMPLES OF THIS.

# CONTROLLING THE LENGTH OF ARRAYS INSIDE RECORDS

- A RECORD COMPONENT DECLARATION MAY TAKE THE FORM  
IDENTIFIER : UNCONSTRAINED ARRAY TYPE NAME INDEX CONSTRAINT ;
- DISCRIMINANTS MAY BE USED WITHIN THE INDEX CONSTRAINT TO SPECIFY BOUNDS OF THE ARRAY.
- DIFFERENT RECORDS IN THE RECORD TYPE MAY HAVE ARRAY-VALUED COMPONENTS OF DIFFERENT SIZES. THE SIZE IS DETERMINED BY THE VALUE OF THE DISCRIMINANTS.

## INSTRUCTOR NOTES

- EMPHASIZE THE ABSTRACT USE OF `Varying_String_Type` BEFORE DISCUSSING THE TYPE DECLARATION ITSELF.
  - MENTION THAT `Word` IS INITIALLY SET TO THE `Empty_Varying_String` IN THE OBJECT DECLARATION, WHERE THE MAXIMUM SIZE IS SET TO 80.
  - MENTION THAT EACH CALL TO CATENATE INCREASES THE LENGTH OF THE STRING OBJECT WORD BY ONE.
- NOW DISCUSS THE TYPE DECLARATION
  - CONSIDER OUTLINING THE CATENATE PROCEDURE  

```
procedure Catenate (Word : in out Varying_String_Type; C : in Character) is
begin
    if Word.Current_Length < Word.Maximum_Length then
        Word.Current_Length := Word.Current_Length + 1;
        Word.Contents (Word.Current_Length) := C;
    else
        -- error processing
        end if;
    end Catenate;
```
- MENTION THAT OPERATIONS ON `Varying_String_Type` OBJECTS WOULD BE PERFORMED THROUGH SUBPROGRAMS.

# EXAMPLE OF A DISCRIMINANT CONTROLLING ARRAY BOUNDS

- A TYPE FOR REPRESENTING CHARACTER STRINGS OF MANY POSSIBLE LENGTHS.
- FROM AN ABSTRACT POINT OF VIEW, THE CURRENT LENGTH OF A Varying\_String\_Type OBJECT MAY CHANGE DURING PROGRAM EXECUTION, UP TO A SPECIFIED MAXIMUM.

```
Word : Varying_String_Type (Maximum_Length => 80) := Empty_Varying_String;  
C : Character;  
...  
loop  
  Get (C);  
  exit when C = ' ';  
  Catenate (Word, C);  
end loop;
```

- TYPE DECLARATION

```
type Varying_String_Type (Maximum_Length : Positive) is  
  record  
    Current_Length : Natural;  
    Contents       : String (1 .. Maximum_Length);  
  end record;
```



## ANOTHER EXAMPLE

- TYPE DECLARATIONS

```
type Matrix_Type is
    array (Positive range<>, Positive range<>) of Float;

type Square_Type (Size : Positive) is
    record
        Square_Part : Matrix_Type (1 .. Size, 1 .. Size);
    end record;
```

- THE Square\_Part COMPONENT OF A Square\_Type RECORD IS ALWAYS A MATRIX WITH  
THE SAME NUMBER OF ROWS AND COLUMNS

- OBJECT DECLARATIONS

```
A : Square_Type (5);  -- A.Square_Part is a 5x5 Matrix,
B : Square_Type (10); -- B.Square_Part is a 10x10 Matrix.
```



INSTRUCTOR NOTES

# NESTING RECORD TYPES WITH DISCRIMINANTS

- A RECORD TYPE WITH DISCRIMINANTS MAY BE USED AS A COMPONENT OF SOME LARGER RECORD TYPE.
- A DISCRIMINANT OF THE LARGER RECORD TYPE MAY BE USED IN A DISCRIMINANT CONSTRAINT FOR THE COMPONENT.
- EXAMPLE:

```
type Message_Type (Message_Size_Limit : Positive) is
  record
    Origin, Destination : Transmission_Line_Type;
    Text                 : Varying_String_Type (Maximum_Length => Message_Size_Limit);
  end record;
```

## INSTRUCTOR NOTES

- RECALL THAT WE SAW THIS EXAMPLE EARLIER, WITHOUT DISCRIMINANTS; THIS IS A MORE LOGICAL REPRESENTATION.
- Requested\_Length AND Maximum\_Buffer\_Length\_Needed CAN BE CONSTANTS, VARIABLES OR FUNCTION CALLS.
- OTHER DISCUSSIONS OF EXPRESSION EVALUATION AND DISCRIMINANTS OCCUR AFTER SUBTYPES OF RECORD TYPES ARE INTRODUCED.

# USING DISCRIMINANTS AS DEFAULT INITIAL VALUES OF COMPONENTS

- EXAMPLE

```
type Buffer_Type (Initial_Length, Maximum_Length : Natural) is
  record
    Current_Length : Natural := Initial_Length;
    Contents       : String (1 .. Maximum_Length);
  end record;
```

- EXPRESSIONS IN DISCRIMINANT CONSTRAINTS ARE EVALUATED WHEN THE DECLARATION  
CONTAINING THE CONSTRAINT IS ELABORATED

- EXAMPLE

```
Buffer : Buffer_Type
  (Initial_Length => Requested_Length,
   Maximum_Length => Maximum_Buffer_Length_Needed);
```

WHEN THIS OBJECT DECLARATION IS ELABORATED, Requested\_Length AND  
Maximum\_Buffer\_Length\_Needed ARE EVALUATED. THESE VALUES ARE USED FOR  
Initial\_Length AND Maximum\_Length.

# INSTRUCTOR NOTES

- THE FOURTH USE IS DISCUSSED ON THE NEXT SLIDE.
- RULES FOR EVALUATION OF THE DISCRIMINANT VALUES ARE DISCUSSED LATER.



# ALLOWABLE USES OF DISCRIMINANTS IN RECORD TYPE DECLARATIONS

- THERE ARE FOUR ALLOWABLE USES:
  - FOLLOWING THE WORD case IN A VARIANT PART.
  - IN AN INDEX CONSTRAINT OF A RECORD COMPONENT.
  - IN A DISCRIMINANT CONSTRAINT OF A RECORD COMPONENT.
  - AS THE DEFAULT INITIAL VALUE OF A COMPONENT.
  
- IN EACH CASE, THE DISCRIMINANT MUST APPEAR AS A FULL EXPRESSION, NOT AS PART OF A LARGER EXPRESSION.

## INSTRUCTOR NOTES

- WE WILL SEE EXAMPLES OF SUCH RECORD TYPES IN A FEW SLIDES.

# DEFAULT INITIAL VALUES FOR DISCRIMINANTS

- A RECORD TYPE DECLARATION MUST PROVIDE DEFAULT INITIAL VALUES FOR ALL OF ITS DISCRIMINANTS OR FOR NONE OF THEM.
- IF DEFAULT INITIAL VALUES ARE PROVIDED, AN OBJECT IN THE TYPE MAY BE DECLARED WITHOUT A DISCRIMINANT CONSTRAINT. IF DEFAULT INITIAL VALUES ARE NOT PROVIDED, EACH OBJECT IN THE TYPE MUST BE DECLARED WITH A DISCRIMINANT CONSTRAINT.
- AN OBJECT DECLARED WITH A DISCRIMINANT CONSTRAINT IS CONSTRAINED. ITS DISCRIMINANTS MUST KEEP THE SAME VALUES FOR THE LIFE OF THE OBJECT.
- AN OBJECT DECLARED WITHOUT A DISCRIMINANT CONSTRAINED IS UNCONSTRAINED. IT MAY TAKE ON VALUES WITH DIFFERENT DISCRIMINANT COMPONENTS DURING ITS LIFETIME.



# INSTRUCTOR NOTES

- WHEN A RECORD AGGREGATE IS USED, THE VALUE FOR THE DISCRIMINANT MAY NOT BE A VARIABLE OR FUNCTION CALL. THIS WILL BE DISCUSSED LATER, SO JUST MENTION IT FOR NOW.



# CHANGING THE DISCRIMINANTS OF UNCONSTRAINED OBJECTS

- IT IS ILLEGAL TO CHANGE THE DISCRIMINANT COMPONENT OF A RECORD BY ITSELF.  
REASON: THIS DISCRIMINANT DETERMINES WHAT OTHER DATA THE RECORD MAY CONTAIN. CHANGING ONLY THE DISCRIMINANT COULD LEAD TO AN INCONSISTENT RECORD.
- IT IS POSSIBLE TO ASSIGN AN ENTIRE RECORD VALUE WITH DIFFERENT DISCRIMINANT COMPONENTS TO AN UNCONSTRAINED RECORD OBJECT.
- SPECIFICALLY, DISCRIMINANT COMPONENTS MAY NEVER APPEAR
  - ON THE LEFTHAND SIDE OF :=
  - AS AN ACTUAL PARAMETER OF MODE out OR in out.

# INSTRUCTOR NOTES

- SINCE Sensor\_Reading IS UNCONSTRAINED, EITHER CONSTRAINED OBJECT MAY BE ASSIGNED TO IT.
- THE FIRST ILLEGAL ASSIGNMENT ATTEMPTS TO CHANGE THE DISCRIMINANT VALUE OF A CONSTRAINED OBJECT.
- THE SECOND ILLEGAL ASSIGNMENT ATTEMPTS TO DIRECTLY CHANGE A DISCRIMINANT VALUE.

# EXAMPLE - CHANGING DISCRIMINANTS OF UNCONSTRAINED OBJECTS

```
Sensor_Reading : Sensor_Reading_Type;           -- Unconstrained
Valid_Reading  : Sensor_Reading_Type (Valid => True);  -- Constrained
Invalid_Reading : Sensor_Reading_Type (Valid => False); -- Constrained
...
Sensor_Reading := Valid_Reading;
Sensor_Reading := Invalid_Reading;
...
Valid_Reading := Invalid_Reading;           -- Illegal
Sensor_Reading.Valid := True;               -- Illegal
```

## INSTRUCTOR NOTES

- THIS EXAMPLE SHOWS THE USE OF RECORD TYPES WITH DISCRIMINANTS AS PROGRAM PARAMETERS.
- THIS SUBPROGRAM COPIES ONE `Varying_String_Type` OBJECT TO ANOTHER
  - IF THE `Maximum_Length` OF THE `To String` IS LESS THAN THE `Current_Length` OF THE `From String`, THEN THE `From String` IS TRUNCATED TO THE `Maximum_Length` OF THE `To String` AND ASSIGNED TO THE `To String`
  - WE NEEDED THE CAPABILITY OF EXAMINING THE DISCRIMINANT VALUE `Maximum_Length` OF THE `out` PARAMETER
  - A DISCRIMINANT OF A RECORD OBJECT ALWAYS HAS A VALUE. THIS IS ONE OF THE CONSISTENCY RULES WE WILL SEE LATER

# EXAMPLE OF SUBPROGRAM PARAMETERS WITH DISCRIMINANTS

```
procedure Copy_String
  (From : in Varying_String_Type;
   To   : out Varying_String_Type) is
begin
  if From.Current_Length <= To.Maximum_Length then
    To.Current_Length := From.Current_Length;
    To.Contents (1 .. To.Current_Length) := From.Contents (1 .. From.Current_Length);
  else
    To.Current_Length := To.Maximum_Length;
    To.Contents (1 .. To.Maximum_Length) := From.Contents (1 .. To.Maximum_Length);
  end if;
end Copy_String;

● To.Maximum_Length IS EXAMINED EVEN THOUGH TO IS OF MODE out.
- THIS IS LEGAL SINCE Maximum_Length IS A DISCRIMINANT
- ILLEGAL TO EXAMINE To.Contents

● STILL CANNOT ASSIGN TO DISCRIMINANT DIRECTLY.

● CANNOT CHANGE THE VALUE OF THE DISCRIMINANT THROUGH A RECORD ASSIGNMENT UNLESS THE
  PARAMETER IS NOT CONSTRAINED.
```

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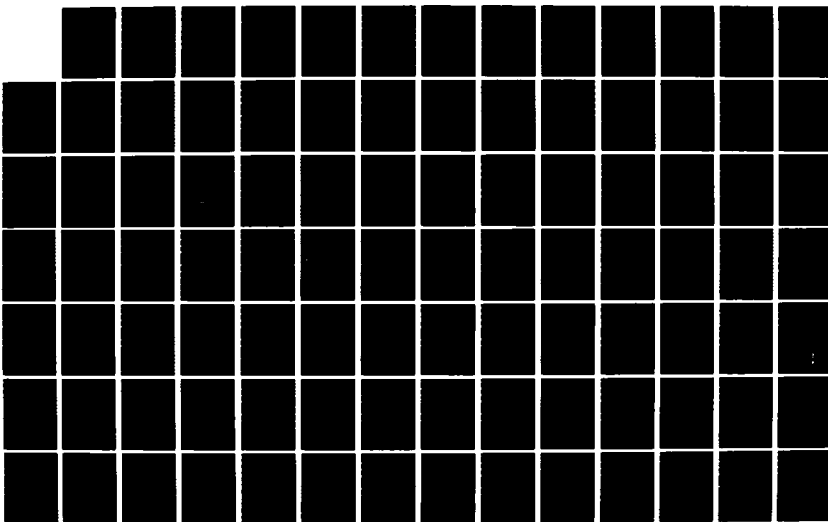
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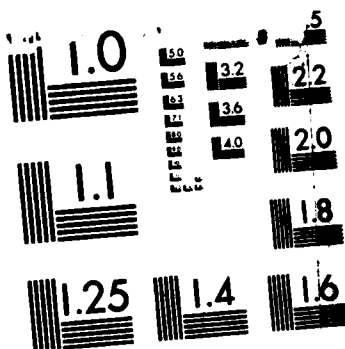
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## INSTRUCTOR NOTES

- THIS VERSION OF Copy\_String IS SIMILAR TO THE PREVIOUS VERSION, EXCEPT WHEN THE Current\_Length OF THE To STRING EXCEEDS THE Maximum\_Length OF THE To STRING,
  1. TRUNCATION OCCURS ONLY IF To IS A CONSTRAINED OBJECT
  2. IF To IS UNCONSTRAINED, THEN IT IS ASSIGNED A RECORD AGGREGATE THAT CHANGES THE Maximum\_Length DISCRIMINANT VALUE TO BE THE VALUE OF THE Current\_Length OF THE From STRING
- TO DETERMINE WHETHER THE OBJECT IS CONSTRAINED, THE CONSTRAINED ATTRIBUTE IS USED.
- ANOTHER POINT OF VIEW MIGHT BE TO INDICATE AN ERROR IF To IS CONSTRAINED. THIS SHOULD BE MENTIONED.

## USING THE Constrained ATTRIBUTE

```
procedure Copy String
  (From : in Varying_String_Type;
   To   : out Varying_String_Type) is
begin
  if From.Current_Length = To.Maximum_Length then
    To.Current_Length := From.Current_Length;
    To.Contents(1 .. From.Current_Length) := From.Contents(1 .. From.Current_Length);
  elsif To'Constrained then
    To.Current_Length := To.Maximum_Length;
    To.Contents(1 .. To.Maximum_Length) := From.Contents(1 .. To.Maximum_Length);
  else
    To := (Maximum_Length => From.Current_Length,
           Current_Length => From.Current_Length,
           Contents      => From.Contents(1 .. From.Current_Length));
  end if;
end Copy_String;
```

- IF X IS A VALUE IN A RECORD TYPE WITH DISCRIMINANTS, THE X'Constrained HAS THE VALUE True; OTHERWISE X'Constrained HAS THE VALUE False.

## INSTRUCTOR NOTES

- THIS EXAMPLE ILLUSTRATES THE USE OF A RECORD TYPE WITH DISCRIMINANTS AS THE COMPONENT TYPE OF AN UNCONSTRAINED ARRAY AND AS THE RESULT TYPE OF A FUNCTION.
- THE FUNCTION IS PASSED A LIST OF SENSOR READINGS. IF MORE THAN HALF THE SENSOR READINGS ARE VALID, THEN AN AVERAGED SENSOR READING IS RETURNED; OTHERWISE AN INVALID READING IS RETURNED.

## ANOTHER SUBPROGRAM EXAMPLE

```
type Sensor_Reading_List_Type is array (Positive range <>) of Sensor_Reading_Type;

function Average_Reading (Sensor_Reading_List : Sensor_Reading_List_Type)
    return Sensor_Reading_Type is
    Number_Valid : Natural := 0;
    Valid_Sum    : Float   := 0.0;
begin
    for I in Sensor_Reading_List'Range loop
        if Sensor_Reading_List (I).Valid then
            Number_Valid := Number_Valid + 1;
            Valid_Sum    := Valid_Sum + Sensor_Reading_List (I).Reading_Part;
        end if;
    end loop;

    if Number_Valid > Sensor_Reading_List'Length/2 then
        return (True, Valid_Sum/Float(Number_Valid));
    else
        return (Valid => False);
    end if;
end Average_Reading;
```

# INSTRUCTOR NOTES

- ITEM 1

- Ada DOES NOT ALLOW A RECORD OBJECT IN A RECORD TYPE WITH DISCRIMINANTS TO BE CREATED UNLESS A VALUE CAN BE DETERMINED FOR EACH DISCRIMINANT.

- ITEM 2

- IT IS NOT LEGAL, FOR EXAMPLE, TO REFER TO THE Reading\_Part COMPONENT OF A Sensor\_Reading\_Type OBJECT UNLESS ITS VALID COMPONENT HAS THE VALUE True.

- ITEM 3

- THE RECORD AGGREGATE (False, 10.3) IS INVALID FOR A Sensor\_Reading\_Type OBJECT SINCE A Sensor\_Reading\_Type OBJECT WITH False FOR ITS DISCRIMINANT, HAS NO Reading\_Part COMPONENT.

# CONSISTENCY RULES

- DISCRIMINANTS ALWAYS HAVE VALUES.
- REFERENCES TO COMPONENTS MUST BE CONSISTENT WITH DISCRIMINANTS.
- AGGREGATES MUST BE CONSISTENT.
- DISCRIMINANTS CANNOT BE CHANGED BY THEMSELVES
  - NOT THROUGH ASSIGNMENT (:=)
  - NOT THROUGH SUBPROGRAM CALLS

# INSTRUCTOR NOTES

- REMIND THE CLASS THAT THEY HAVE SEEN SUBTYPES BEFORE.
- IF THE CLASS HAS PROBLEMS WITH RECORD SUBTYPES, CONSIDER USING THE Aircraft\_Type AS ANOTHER SOURCE OF EXAMPLES.

# SUBTYPES OF RECORD TYPES

## • TWO FORMS FOR DECLARATIONS

```

subtype SUBTYPE NAME is RECORD TYPE NAME
subtype SUBTYPE NAME is RECORD TYPE NAME DISCRIMINANT CONSTRAINT;

```

- WITH THE FIRST FORM, THE SUBTYPE CONSISTS OF THE ENTIRE RECORD TYPE  
EXAMPLE:

```

subtype Line_Type is Varying_String_Type;

```

- WITH THE SECOND FORM, THE SUBTYPE CONSISTS OF THOSE RECORD VALUES THAT  
SATISFY DISCRIMINANT CONSTRAINT  
EXAMPLES:

```

subtype Valid_Sensor_Reading_Subtype is Sensor_Reading_Type (Valid => True);
-- THIS SUBTYPE CONSISTS OF ALL VALUES IN Sensor_Reading_Type
-- EXCEPT Sensor_Reading_Type (Valid => False)
subtype Line_of_80 is Varying_String_Type (80);
-- THIS SUBTYPE CONSISTS OF ALL VALUES IN Varying_String_Type
-- WHOSE Maximum_Length COMPONENT HAS THE VALUE OF 80.

```



## INSTRUCTOR NOTES

- THIS SLIDE SHOWS THE CLASS THAT MEMBERSHIP TESTS ALSO EXIST FOR RECORD SUBTYPES.



# MEMBERSHIP TESTS

- TO DETERMINE IF A RECORD VALUE BELONGS TO A PARTICULAR SUBTYPE, DISCRIMINANTS CAN BE TESTED
    - if Sensor\_Reading.Valid then
      - ...
      - end if;
  - MEMBERSHIP TESTS CAN ALSO BE USED
    - if Sensor\_Reading in Valid\_Sensor\_Reading\_Subtype then
      - ...
      - end if;
- ESPECIALLY USEFUL IF THE RECORD TYPE HAS MORE THAN ONE DISCRIMINANT.

INSTRUCTOR NOTES

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000

# EXPRESSIONS INVOLVING DISCRIMINANTS

- FOR A RECORD TYPE HAVING A VARIANT, AN AGGREGATE FOR THE RECORD TYPE MAY NOT HAVE VARIABLES OR FUNCTION CALLS IN ANY EXPRESSION FOR DISCRIMINANTS SELECTING THE CURRENT VARIANT.

EXAMPLE: ASSUMING Aircraft\_Id : Aircraft\_Identification\_Type;

```
(Aircraft_Identification => Aircraft_Id,  
Tracking_Data_Part      => Tracking_Data,  
Threat_Level_Part       => Low_Threat)
```

IS AN INVALID AGGREGATE SINCE Aircraft\_Identification SELECTS THE VARIANT

EXAMPLE: ASSUMING Number\_Of\_Blanks : Natural;

```
(Maximum_Length => Number_Of_Blanks,  
Current_Length  => Number_Of_Blanks,  
Content         => (1 .. Number_Of_Blanks => ' '))
```

- THE DEFAULT INITIAL VALUE EXPRESSION IN A DISCRIMINANT SPECIFICATION IS EVALUATED WHEN A RECORD OBJECT IS CREATED, AND ONLY IF VALUES ARE NOT GIVEN IN A DISCRIMINANT CONSTRAINT OR IN AN INITIAL VALUE.
- EXPRESSIONS IN A DISCRIMINANT CONSTRAINT ARE EVALUATED WHEN THE DECLARATION CONTAINING THE CONSTRAINT IS ELABORATED.

```
Buffer_Size : Positive;
```

```
...  
subtype Buffer_Subtype is Varying_String_Type (Maximum_Length => Buffer_Size);
```

WHEN THIS SUBTYPE IS ELABORATED, THE CURRENT VALUE OF Buffer\_Size IS USED TO DETERMINE THE VALUE OF Maximum\_Length. THIS STAYS FIXED, EVEN IF Buffer\_Size CHANGES.

INSTRUCTOR NOTES


# **SECTION 10**

## **ACCESS TYPES**

INSTRUCTOR NOTES

THIS SLIDE IS JUST TO LET THE STUDENTS "TAKE A STEP BACK" AND PUT INTO PERSPECTIVE ALL  
OF THE CLASSES OF TYPES.

# CLASSES OF TYPES

- SCALAR TYPES
  - INTEGER
  - REAL
  - ENUMERATION
- COMPOSITE TYPES
  - ARRAY
  - RECORD
-  ACCESS TYPES
- PRIVATE TYPES



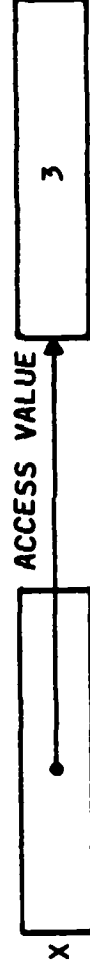
# INSTRUCTOR NOTES

A NULL ACCESS VALUE IS DENOTED (IN PROGRAMS AND IN OUR DIAGRAMS) BY THE RESERVED WORD  
"null."

# ACCESS VALUES

AN ACCESS VALUE IS AN INDIRECT REFERENCE TO AN OBJECT CONTAINING SOME OTHER VALUE.

ACCESS VALUES ARE ALSO KNOWN AS POINTER VALUES. WE DRAW AN INDIRECT REFERENCE TO AN OBJECT AS AN ARROW POINTING TO THAT OBJECT.



X { CONTAINS AN INDIRECT REFERENCE TO  
POINTS TO  
DESIGNATES } AN OBJECT CONTAINING 3

THE SPECIAL ACCESS VALUE NULL DOES NOT POINT TO ANY OBJECT.

# INSTRUCTOR NOTES

THE BOXES ON THE RIGHT REPRESENT TWO DIFFERENT OBJECTS, BOTH CONTAINING THE NUMBER 3.

THE BOXES ON THE LEFT REPRESENT THREE VARIABLES NAMED A, B, AND C, EACH CONTAINING ACCESS VALUES.

A AND B POINT TO THE SAME OBJECT, SO THEY HOLD THE SAME ACCESS VALUE.

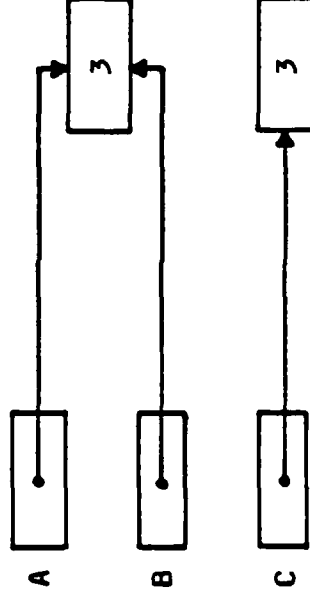
B AND C POINT TO DIFFERENT OBJECTS, SO THEY HOLD DIFFERENT ACCESS VALUES. IT IS IRRELEVANT THAT THESE TWO OBJECTS HAPPEN TO HAVE THE SAME CONTENTS.

## ACCESS VALUES (Continued)

TWO ACCESS VALUES ARE EQUAL IF THEY DESIGNATE THE SAME OBJECT.

(TWO ARROWS DEPICT THE SAME ACCESS VALUE IF THEY POINT TO THE SAME PLACE.)

ACCESS VALUES DESIGNATING DIFFERENT OBJECTS WITH IDENTICAL CONTENTS ARE DIFFERENT ACCESS VALUES.



A = B, BUT B  $\neq$  C

## INSTRUCTOR NOTES

THE NOTION OF ACCESS VALUE MAY BE ALIEN TO FORTRAN PROGRAMMERS, BUT ASSEMBLY LANGUAGE PROGRAMMERS ARE FAMILIAR WITH SOMETHING QUITE SIMILAR -- ADDRESSES USED AS VALUES.

ACCESS VALUES MAY BE USED IN ASSIGNMENT STATEMENTS AND COMPARISONS FOR EQUALITY OR INEQUALITY. THEY MAY ALSO BE USED TO PROVIDE ACCESS TO THE OBJECTS THEY DESIGNATE.

INTERNALLY AN ACCESS VALUE DESIGNATING AN OBJECT MAY OR MAY NOT BE REPRESENTED AS THE ADDRESS OF THE OBJECT. THIS DEPENDS ON THE COMPILER AND IS OF NO CONCERN TO THE PROGRAMMER.

# ACCESS VALUES ARE SIMILAR TO ADDRESSES ...

- THEY PROVIDE ACCESS TO ANOTHER OBJECT.
- THEY MAY BE USED AS VALUES THEMSELVES.
- TWO VARIABLES CONTAINING THE SAME  $\left\{ \begin{array}{l} \text{ADDRESS} \\ \text{ACCESS VALUE} \end{array} \right\}$  ARE INDIRECT REFERENCES TO THE SAME OBJECT.

... BUT THERE ARE IMPORTANT DIFFERENCES:

- AN ACCESS VALUE CANNOT POINT TO AN ARBITRARY PLACE IN MEMORY, BUT ONLY TO AN OBJECT OF A PARTICULAR TYPE.
- ACCESS VALUES ARE NOT NUMBERS. THEY CANNOT BE ADDED, SUBTRACTED, MULTIPLIED, OR DIVIDED. ONE ACCESS VALUE IS NOT GREATER THAN OR LESS THAN ANOTHER ACCESS VALUE, I.E., THE RELATIONAL OPERATORS DO NOT APPLY.

## INSTRUCTOR NOTES

DYNAMIC ALLOCATION IS AN ACTION PERFORMED BY A PROGRAM.

IT USUALLY RESULTS FROM EXECUTION OF A STATEMENT THAT CALLS FOR AN OBJECT TO BE ALLOCATED. THE PART OF THE STATEMENT THAT CALLS FOR THE ALLOCATION SPECIFIES THE TYPE OF THE OBJECT TO BE ALLOCATED.

THE OBJECT ALLOCATED IS NEVER A CONSTANT.

[NOTE TO INSTRUCTOR: THE FACT THAT ALLOCATORS ARE EXPRESSIONS WILL BE EXPLAINED IN DETAIL LATER. THE REFERENCE TO STATEMENTS ABOVE IS INTENDED ONLY TO CONVEY THE FACT THAT DYNAMIC ALLOCATION IS CONTROLLED ALGORITHMICALLY.]

# DYNAMIC ALLOCATION

DYNAMIC ALLOCATION IS THE PROCESS OF CREATING AN ALLOCATED VARIABLE DURING PROGRAM EXECUTION:

1. STORAGE FOR THE OBJECT IS SET ASIDE.
2. AN ACCESS VALUE POINTING TO THE OBJECT IS MADE AVAILABLE TO THE PROGRAM.

A DYNAMICALLY ALLOCATED OBJECT IS ALWAYS A VARIABLE OF A SPECIFIED TYPE.

THE PROGRAM MAY ONLY REFER TO THE VARIABLE IN TERMS OF THE ACCESS VALUE POINTING TO IT.



## INSTRUCTOR NOTES

THE DECLARED VARIABLES AND ALLOCATED VARIABLES DO NOT OVERLAP.

ALLOCATED VARIABLES CAN ONLY BE REFERRED TO USING ACCESS VALUES AND ACCESS VALUES CAN ONLY POINT TO ALLOCATED VARIABLES.

[NOTE TO INSTRUCTOR: A DECLARED VARIABLE IS AN OBJECT RESULTING FROM A VARIABLE DECLARATION. A RENAMING DECLARATION IS NOT A VARIABLE DECLARATION, AND A RENAMING DECLARATION LIKE

S : Some\_Type renames Y.all;

ESTABLISHES AN IDENTIFIER NAMING AN ALLOCATED VARIABLE. DO NOT ADDRESS THIS ISSUE UNLESS IT IS BROUGHT UP BY A STUDENT!]

EVERYTHING WE'VE SEEN SO FAR HAS BEEN A DECLARED VARIABLE, NOW WE'RE LOOKING AT ALLOCATED VARIABLES ...

# THE TWO CATEGORIES OF Ada VARIABLES

## DECLARED VARIABLES

- ARISE FROM VARIABLE DECLARATIONS
- REFERRED TO BY THEIR DECLARED NAMES

## → ALLOCATED VARIABLES

- ARISE FROM DYNAMIC ALLOCATION
- REFERRED TO BY THE ACCESS VALUES MADE AVAILABLE DURING DYNAMIC ALLOCATION

ACCESS VALUES NEVER POINT TO DECLARED VARIABLES.

INSTRUCTOR NOTES

PAUSE AT THIS POINT FOR QUESTIONS.

TELL CLASS YOU'VE INTRODUCED CONCEPTS AND NOW YOU'LL GO INTO GREATER DETAIL ON ACCESS VALUES.

# RECAP

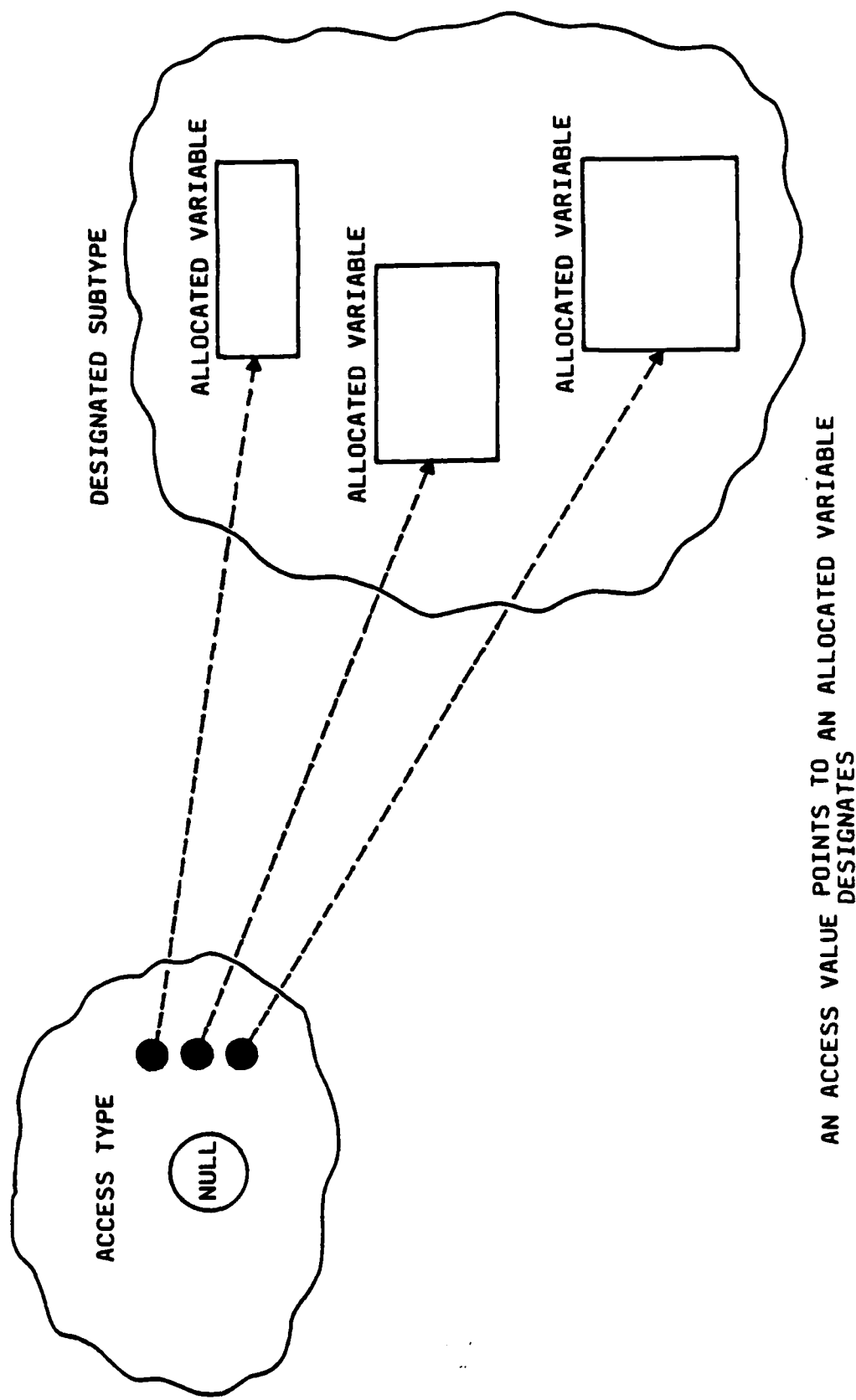
1. ACCESS VALUES ARE INDIRECT REFERENCES (THEY POINT) TO OTHER VARIABLES.
2. VARIABLES MAY BE DECLARED OR ALLOCATED.
3. ALLOCATED VARIABLES ARE ALWAYS POINTED TO BY ACCESS VALUES.  
DECLARED VARIABLES ARE NEVER POINTED TO BY ACCESS VALUES.
4. ALLOCATED VARIABLES MAY ONLY BE REFERRED TO IN TERMS OF THE ACCESS VALUES POINTING TO THEM.

INSTRUCTOR NOTES

THE FOLLOWING SLIDE ANSWERS THE QUESTION, "WHERE DO ACCESS VALUES FIT INTO THE LANGUAGE?"

POINT OUT THE NULL POINTER.

# ACCESS TYPES



## INSTRUCTOR NOTES

AN ACCESS TYPE DECLARATION SPECIFIES THE SUBTYPE OF THE VARIABLES TO BE POINTED TO BY VALUES IN THE ACCESS TYPE. EACH SUCH DECLARATION ESTABLISHES A SEPARATE COLLECTION OF ALLOCATED VARIABLES. TWO ACCESS TYPE DECLARATIONS CAN NAME THE SAME TYPE OR SUBTYPE TO BE DESIGNATED, BUT OBJECTS IN THE TWO ACCESS TYPES CANNOT BOTH DESIGNATE THE SAME ALLOCATED VARIABLE. THIS IS BECAUSE EACH ALLOCATED VARIABLE BELONGS TO EXACTLY ONE COLLECTION.

IP, NP, AND DP ARE VARIABLES CONTAINING ACCESS VALUES.

# ACCESS TYPES

AN ACCESS TYPE IS A TYPE CONSISTING OF ACCESS VALUES.

ALL VALUES IN A GIVEN ACCESS TYPE DESIGNATE ALLOCATED VARIABLES OF A SINGLE SUBTYPE.

## ACCESS TYPE DECLARATION:

type access type name is access designated type or subtype name [Constraint];

## EXAMPLES:

type Integer\_Pointer\_Type is access Integer;  
type Natural\_Pointer\_Type is access Natural;  
type Digit\_Pointer\_Type is access Integer range 0 .. 9;

IP : Integer\_Pointer\_Type;  
NP : Natural\_Pointer\_Type;  
DP : Digit\_Pointer\_Type;

OBJECTS IN ACCESS TYPE (SUCH AS IP, NP, AND DP) ARE AUTOMATICALLY INITIALIZED TO NULL UNLESS ANOTHER VALUE IS GIVEN IN THE OBJECT DECLARATION.



## INSTRUCTOR NOTES

LIKE A FUNCTION CALL, AN ALLOCATOR REQUIRES CERTAIN ACTIONS TO BE PERFORMED IN ORDER TO PRODUCE A VALUE.

REMINDER: DYNAMIC OBJECTS ARE CREATED DYNAMICALLY AND EXPLICITLY DURING PROGRAM EXECUTION.

# ALLOCATORS

ALLOCATED VARIABLES ARE CREATED BY EVALUATION OF AN ALLOCATOR.

AN ALLOCATOR IS AN EXPRESSION.

EVALUATION OF THIS EXPRESSION CONSISTS OF TWO STEPS:

1. A VARIABLE OF A SPECIFIED SUBTYPE IS DYNAMICALLY ALLOCATED.
2. AN ACCESS VALUE POINTING TO THE NEW ALLOCATED VARIABLE BECOMES THE VALUE OF THE EXPRESSION.

## INSTRUCTOR NOTES

THIS SLIDE PROVIDES THE STUDENTS WITH A BRIEF LOOK AT ALLOCATORS. AVOID GETTING CAUGHT IN SYNTAX RULES, THE FORMS OF AN ALLOCATOR ARE PRESENTED ON THE FOLLOWING SLIDE.

# EXAMPLES OF ALLOCATORS

```
CONTEXT:  type Integer_Pointer_Type is access Integer;
          type Cell_Type is
            record
              Value : String (1 .. 8);
              Priority : Positive;
            end record;
          type Link_Type is access Cell_Type;
          type Bit_String_Type is array (Integer range <>) of Boolean;
          type Bit_String_Pointer_Type is access Bit_String_Type;
```

## EXAMPLES:

```
A : Integer_Pointer_Type := new Integer;
Halfword : Bit_String_Pointer_Type := new Bit_String_Type (1 .. 4);

Cell_1, Cell_2 : Link_Type;
Cell_1 := new   Cell_Type ' (*****M100", 1);
Cell_2 := new   Cell_Type ' (Value => "*****M200", Priority => 2);
```

INSTRUCTOR NOTES

THE THIRD FORM DEFINES THE CONTENTS OF THE ALLOCATED OBJECT BEING CREATED. THE OTHER FORMS DO NOT.

THE PARENTHESES FORM PART OF THE INDEX CONSTRAINT OR DISCRIMINANT CONSTRAINT.

# FORMS OF AN ALLOCATOR

- new type or subtype name
- new unconstrained array subtype name index constraint
- new type or subtype name ( initial value )

-- IF THE INITIAL VALUE IS AN AGGREGATE, THE RESULTING DOUBLE SET OF PARENTHESES MAY BE ABBREVIATED BY A SINGLE SET, E.G.

new Vector'(1,2,3,4)

INSTEAD OF

new Vector'((1,2,3,4))

- new unconstrained record subtype name discriminant constraint

## INSTRUCTOR NOTES

THE DECLARATION OF A AND B IS EQUIVALENT IN EVERY RESPECT TO SEPARATE AND IDENTICAL DECLARATIONS FOR EACH VARIABLE. IN PARTICULAR, THE ALLOCATOR SPECIFYING THE INITIAL VALUE IS EVALUATED TWICE, CREATING TWO ALLOCATED VARIABLES DESIGNATED BY TWO DIFFERENT ACCESS VALUES. EACH ALLOCATED VARIABLE IS INITIALIZED TO 3.

BECAUSE NO INITIAL VALUE IS SPECIFIED FOR C, C IS INITIALIZED TO null.

THE ASSIGNMENT C := B MAKES C DESIGNATE THE SAME OBJECT AS B.

THE ASSIGNMENT B := new Integer (4) CAUSES THE CREATION OF A NEW ALLOCATED VARIABLE CONTAINING THE VALUE 4, AND PLACES THE ACCESS VALUE DESIGNATING THAT VARIABLE IN B.

C CONTINUES TO DESIGNATE THE VARIABLE ORIGINALLY DESIGNATED BY B.

POINT OUT THAT THE ALLOCATOR HAS BEEN EVALUATED TWICE, ONCE FOR A AND ONCE FOR B. IF IT HAD ONLY BEEN ALLOCATED ONCE, THEN A AND B WOULD BOTH BE POINTING TO THE SAME ALLOCATED VARIABLE.

# USE OF ALLOCATORS

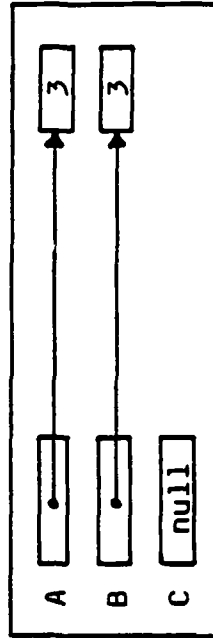
procedure Allocator\_Example is

type Integer\_Pointer\_Type is access Integer;

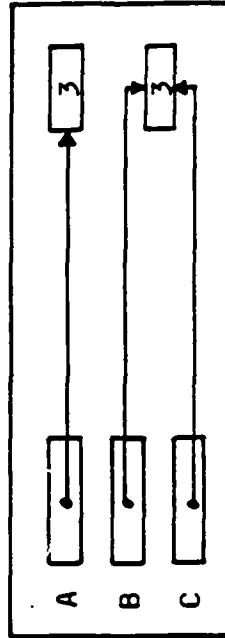
A, B : Integer\_Pointer\_Type := new Integer'(3); -- ALLOCATOR EVALUATED TWO TIMES

C : Integer\_Pointer\_Type; -- DEFAULT INITIAL VALUE IS NULL

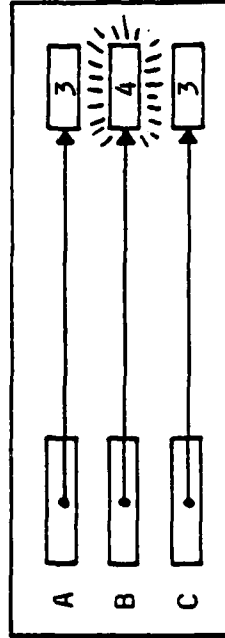
begin -- Allocator\_Example



C := B;



B := new Integer'(4);



end Allocator\_Example;



## INSTRUCTOR NOTES

THIS SLIDE EMPHASIZES A RULE GIVEN TWO SLIDES EARLIER: WHEN ALLOCATING A VARIABLE IN AN UNCONSTRAINED ARRAY SUBTYPE, YOU MUST PROVIDE EITHER AN INDEX CONSTRAINT (AS WITH A AND B) OR AN INITIAL VALUE (AS WITH C AND D; C IS INITIALIZED WITH A NAMED AGGREGATE, D WITH A POSITIONAL ONE).

AN APOSTROPHE IS USED WITH AN INITIAL VALUE, BUT NOT WITH AN INDEX CONSTRAINT.

WHEN AN INITIAL VALUE IS GIVEN, IT MUST BE POSSIBLE TO DEDUCE THE INDEX BOUNDS FROM THE INITIAL VALUE. THEREFORE, WHEN THE ARRAY SUBTYPE IS NOT CONSTRAINED, AN AGGREGATE GIVING THE INITIAL VALUE MAY NOT CONTAIN others. (FOR A POSITIONAL AGGREGATE, THE FIRST VALUE OF THE INDEX SUBTYPE -- Natural'First, OR 0, IN THIS CASE -- IS USED AS THE LOWER BOUND OF THE ARRAY.)

IF AN ARRAY SUBTYPE IS CONSTRAINED, YOU DON'T HAVE TO SPECIFY AN INITIAL VALUE OR AN INDEX CONSTRAINT.

RATIONALE IS THAT THE ALLOCATOR NEEDS ENOUGH INFORMATION TO KNOW HOW BIG OF AN ARRAY TO ALLOCATE.

# ALLOCATION OF ARRAYS

- WHEN ALLOCATING A VARIABLE IN AN UNCONSTRAINED ARRAY TYPE, YOU MUST SPECIFY EITHER AN INDEX CONSTRAINT OR AN INITIAL VALUE. (INITIAL VALUES ARE PRECEDED BY APOSTROPHES; INDEX CONSTRAINTS ARE NOT.)

## EXAMPLE

procedure Array\_Allocation is

type Vector\_Type is array (Natural range <>) of Float;

type Vector\_Pointer\_Type is access Vector\_Type;

A,B,C,D : Vector\_Pointer\_Type;

begin

... A := new Vector\_Type (1 .. 10);

... B := new Vector\_Type (20 .. 100);

...

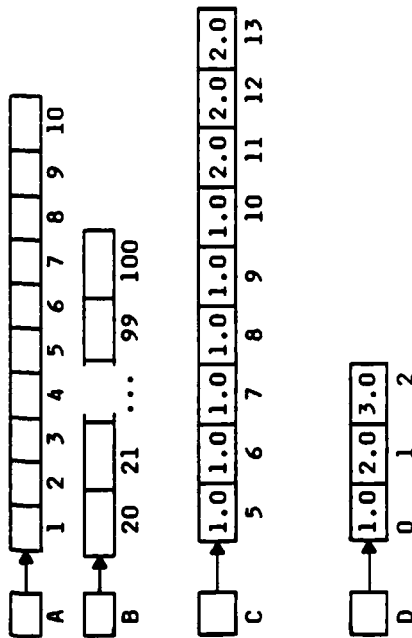
C := new Vector\_Type '(5 .. 10 => 1.0, 11 .. 13 => 2.0);

...

D := new Vector\_Type '(1.0, 2.0, 3.0);

...

end Array\_Allocation;



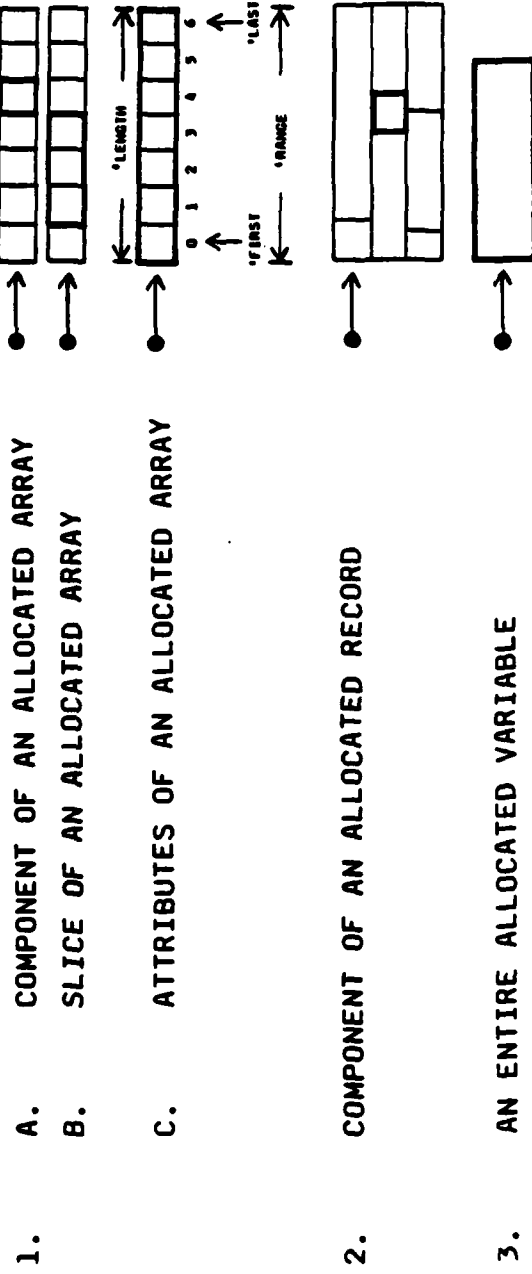
## INSTRUCTOR NOTES

THE PROCESS OF GETTING YOUR HANDS ON AN ALLOCATED VARIABLE, GIVEN AN ACCESS VALUE DESIGNATING THAT VARIABLE, IS SOMETIMES CALLED DEREFERENCING.

THE ARROWS POINT TO THE VALUE AS A WHOLE, NOT INDIVIDUAL COMPONENTS.

# REFERRING TO ALLOCATED VARIABLES

- ALLOCATED VARIABLES AND COMPONENTS OF THOSE VARIABLES MAY BE REFERRED TO IN TERMS OF ACCESS VALUES POINTING TO THEM.
- THEY MAY BE REFERRED TO ON EITHER SIDE OF AN ASSIGNMENT STATEMENT.
- SPECIAL NOTATION FOR DIFFERENT CASES:



EXAMPLES OF EACH TO FOLLOW...

## INSTRUCTOR NOTES

IF SP IS AN ACCESS VALUE DESIGNATING AN N-DIMENSIONAL ARRAY, THEN SP FOLLOWED BY A PARENTHESIZED LIST OF N SUBSCRIPTS NAMES A COMPONENT OF THE DESIGNATED ARRAY.

ON THE SLIDE, S CONTAINS A STRING OF LENGTH 5, THAT IS, AN ARRAY CONTAINING FIVE COMPONENTS OF TYPE Character. SP CONTAINS AN ACCESS VALUE DESIGNATING A STRING OF LENGTH 12.

IN THE FIRST ASSIGNMENT STATEMENT, S(1) REFERS TO THE FIRST COMPONENT OF S ITSELF, WHILE SP (12) REFERS TO THE TWELFTH COMPONENT OF THE ARRAY DESIGNATED BY SP. THE EFFECT OF THIS ASSIGNMENT IS TO REPLACE THE PERIOD FOLLOWING "Hello there" WITH AN EXCLAMATION POINT.

(AN EXPRESSION LIKE SP(12) CAN ALSO APPEAR IN EXPRESSIONS, NAMING THE VALUE OF THE TWELFTH COMPONENT OF THE ARRAY DESIGNATED BY SP. THE SLIDE DOES NOT ILLUSTRATE THIS POSSIBILITY.)

SINCE THE ARRAY DESIGNATED BY SP IS ONE-DIMENSIONAL, IT IS POSSIBLE TO TAKE SLICES OF THE ARRAY. SP FOLLOWED BY A PARENTHESIZED DISCRETE RANGE NAMES A SLICE OF THE ARRAY DESIGNATED BY SP.

IN THE SECOND ASSIGNMENT STATEMENT, SP (1 .. 5), NAMES SUCH A RANGE. THIS ASSIGNMENT REPLACES THE CONTENTS OF S WITH THE STRING "Hello".

IN THE THIRD ASSIGNMENT, SP (7 .. 11) NAMES SUCH A RANGE. THIS ASSIGNMENT REPLACES THE SEVENTH THROUGH ELEVENTH COMPONENTS OF THE ARRAY DESIGNATED BY SP WITH THE CHARACTERS IN S, NAMELY "Hello". THIS LEAVES "Hello Hello!" IN THE ARRAY DESIGNATED BY SP.

AS SHOWN ON THE BOTTOM OF THE SLIDE, AN ATTRIBUTE DESIGNATOR NORMALLY MEANINGFUL ONLY FOR ARRAY OBJECTS CAN BE APPLIED TO SP TO NAME AN ATTRIBUTE OF THE ARRAY DESIGNATED BY SP.

HAVE STUDENTS FILL IN.

SP'LENGTH = 12, SP'FIRST = 1, SP'LAST = 12



# INSTRUCTOR NOTES

IF LP IS AN ACCESS VALUE DESIGNATING A RECORD WITH COMPONENTS LATITUDE AND LONGITUDE, THEN LP.Latitude AND LP.Longitude NAME THE COMPONENTS OF THE DESIGNATED RECORD.

ON THE SLIDE, L CONTAINS A RECORD OF TYPE Location\_Type AND LP CONTAINS AN ACCESS VALUE POINTING TO SUCH A RECORD.

THE FIRST ASSIGNMENT STATEMENT ASSIGNS THE LATITUDE COMPONENT OF THE RECORD DESIGNATED BY LP TO THE LATITUDE COMPONENT OF L.

ANSWERS:	LP : <input type="checkbox"/>	55.75	L :	55.75
		37.70		-77.01

THE SECOND ASSIGNMENT STATEMENT ASSIGNS THE LONGITUDE COMPONENT OF L TO THE LONGITUDE COMPONENT OF THE RECORD DESIGNATED BY LP.

ANSWERS:	LP : <input type="checkbox"/>	55.75	L :	38.90
		-77.01		-77.01

THE NOTION LP.all MEANS THAT ALL THE COMPONENTS OF THE RECORD DESIGNATED BY LP, IN OTHER WORDS, THE ENTIRE RECORD (THE WORD all IS RESERVED, SO IT CANNOT BE THE NAME OF AN ORDINARY RECORD COMPONENT).

THE THIRD ASSIGNMENT STATEMENT ASSIGNS THE ENTIRE RECORD DESIGNATED BY LP TO L.

ANSWERS:	LP : <input type="checkbox"/>	55.75	L :	55.75
		37.70		37.70

THE FOURTH ASSIGNMENT STATEMENT PLACES A NEW Location\_Type VALUE IN THE VARIABLE DESIGNATED BY LP, REPLACING THE ENTIRE RECORD.

ANSWERS:	LP : <input type="checkbox"/>	51.50	L :	38.90
		0.00		-77.01

HAVE STUDENTS FILL IN.

NOTE: HAVE STUDENT REFER TO THE ORIGINAL DEFINITION FOR EACH EXAMPLE.

## 2. COMPONENTS OF ALLOCATED RECORDS

type Location\_Type is  
record

Latitude : Float range -90.0 .. 90.0;

Longitude : Float range -180.0 .. 180.0;

end record;

type Location\_Pointer\_Type is access Location\_Type;

LP : Location\_Pointer\_Type := new Location\_Type'(55.75, 37.70);


L : Location\_Type := (38.90, -77.01);

LP :  Latitude  
Longitude

L :  Latitude  
Longitude

L.Latitude := LP.Latitude;

-- READ THE LATITUDE COMPONENT OF THE RECORD  
-- POINTED TO BY LP

LP : 

L : 

LP.Longitude := L.Longitude;


-- CHANGE THE LONGITUDE COMPONENT OF THE  
-- RECORD POINTED TO BY LP

LP : 

L : 

L := LP.all;

-- READ THE ENTIRE RECORD POINTED TO BY LP

LP : 

L : 

LP.all := (51.50, 0.00);

-- REPLACE THE ENTIRE RECORD POINTED TO BY LP

LP : 

L : 



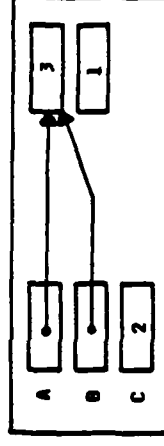
## INSTRUCTOR NOTES

IN FACT, IF X IS ANY NON-NULL ACCESS VALUE, X.all NAMES THE ENTIRE ALLOCATED VARIABLE POINTED TO BY X. THE ALLOCATED VARIABLE DOES NOT HAVE TO BELONG TO A RECORD TYPE.

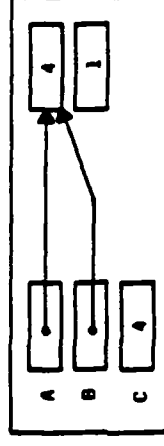
THIS SLIDE SHOWS HOW TO NAME THE INTEGER VARIABLES DESIGNATED BY VALUES OF THE Integer Pointer Type. A.all NAMES THE BOX THAT A POINTS TO, AND B.all NAMES THE BOX THAT B POINTS TO.

THE ALLOCATOR IN THE DECLARATION OF A AND B IS EVALUATED ONCE FOR A AND ONCE FOR B, SO A AND B INITIALLY POINT TO TWO SEPARATE ALLOCATED VARIABLES, EACH CONTAINING THE VALUE 1.

THE FIRST ASSIGNMENT STATEMENT PLACES THE VALUE 3 IN THE BOX POINTED TO BY A. IT IS AN ASSIGNMENT OF INTEGER VALUES. THE SECOND ASSIGNMENT MAKES B POINT TO THAT SAME BOX. IT IS AN ASSIGNMENT OF Integer Pointer Type VALUES.



THE THIRD ASSIGNMENT INCREMENTS THE VARIABLE POINTED TO BY B. SINCE A AND B POINT TO THE SAME BOX AT THIS POINT, A.all AND B.all ARE CURRENTLY TWO DIFFERENT NAMES FOR THE SAME ALLOCATED VARIABLE. INCREMENTING B.all CAUSES A.all TO INCREASE. THUS THE FOURTH ASSIGNMENT TO C.



THE CLASS SHOULD BE GIVEN A MOMENT TO STUDY THE FIFTH ASSIGNMENT AND CONCLUDE THAT IT INCREMENTS B.all (TO 5) AND DOES NOT AFFECT C.

REMEMBER TO FILL IN ARROWS AS WELL AS BOXES.

# USE .all TO NAME ENTIRE ALLOCATED VARIABLES OF ANY TYPE

procedure All\_Example is

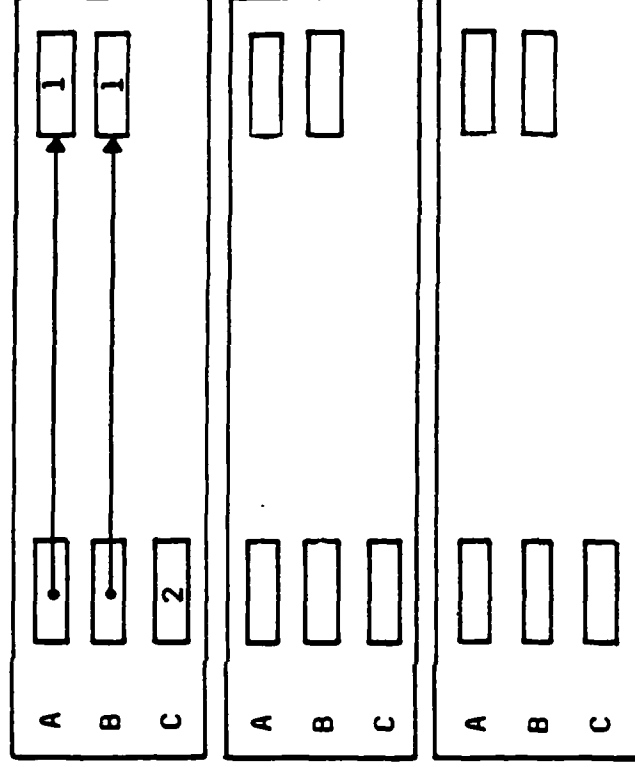
```
type Integer_Pointer_Type is access Integer;
A, B : Integer_Pointer_Type := new Integer'(1);
C : Integer := 2;
```

begin -- All\_Example

```
-----
A.all := 3;
B := A;
```

```
-----
B.all := B.all + 1;
C := A.all;
```

```
-----
A.all := A.all + 1;
-- HOW DOES THIS AFFECT THE VALUE OF B.all? OF C?
end All_Example;
```

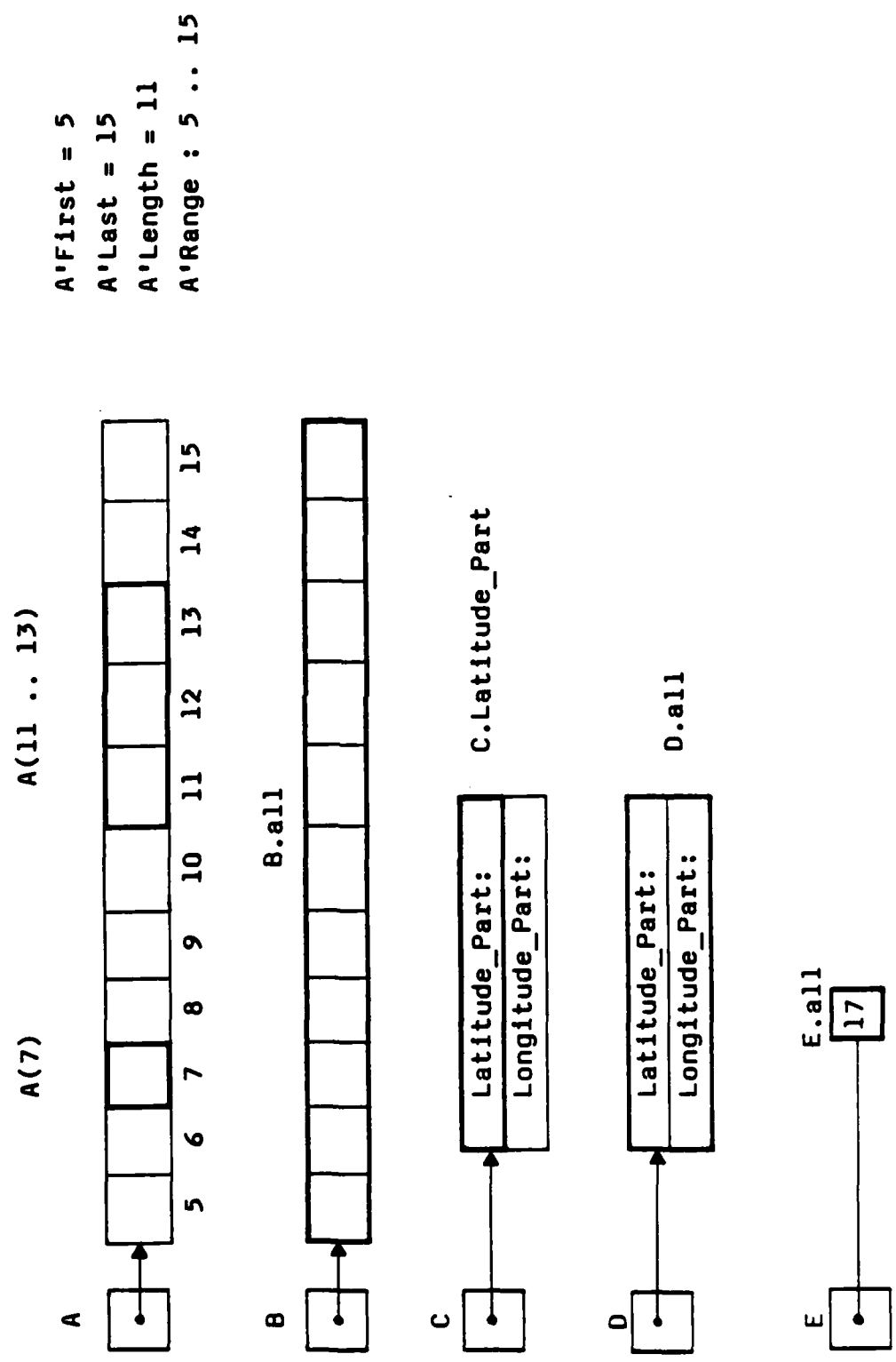


INSTRUCTOR NOTES

REVIEW.



# NAMING ALLOCATED VARIABLES -- SUMMARY



## INSTRUCTOR NOTES

THE FIRST FOUR TOPICS WILL BE COVERED HERE AND THE FIFTH WILL BE COVERED IN L305.

AS WILL BE EXPLAINED LATER, A RAGGED ARRAY IS AN ARRAY WHOSE COMPONENTS THEMSELVES ARE ARRAYS OF DIFFERENT LENGTHS.

# USES OF ACCESS VALUES

1. TO PROVIDE ACCESS TO SHARED DATA.
2. TO BUILD RAGGED ARRAYS.
3. TO AVOID MOVING LARGE AMOUNTS OF DATA.
4. TO CHANGE, AT RUNTIME, THE VARIABLE ASSOCIATED WITH THE NAME.
5. TO DEFINE A DATA TYPE WHOSE OBJECT REFERS TO OTHER OBJECTS OF THE SAME TYPE.

## INSTRUCTOR NOTES

SINCE MOST PEOPLE HAVE MAILING ADDRESSES IDENTICAL TO THEIR RESIDENTIAL ADDRESSES, MOST Person\_Type RECORDS, AS DEFINED ON THE TOP PART OF THE SLIDE, CONTAIN A LARGE AMOUNT OF DUPLICATE INFORMATION.

AN ALTERNATIVE, SHOWN AT THE BOTTOM OF THE SLIDE, IS TO HAVE COMPONENTS OF THE Person\_Type RECORD POINT TO Address\_Type RECORDS. COMPONENTS REPRESENTING THE SAME ADDRESS CAN POINT TO THE SAME Address\_Type RECORD, SO THAT THE ADDRESS NEED ONLY BE STORED IN ONE PLACE.

THE FOLLOWING SLIDE DEPICTS THESE ALTERNATIVES GRAPHICALLY.

THE LAST STATEMENT IS A PUN. IN THE FIRST CASE, P.Residence\_Part MEANS THE STATE PART OF THE COMPONENT OF THE ADDRESS TYPE RECORD P.Residence\_Part. IN THE SECOND CASE, P.Residence\_Part MEANS THE STATE PART COMPONENT OF THE ADDRESS TYPE RECORD POINTED TO BY P.Residence\_Part.

# 1. USE OF ACCESS VALUES TO PROVIDE ACCESS TO SHARED DATA

EXAMPLE 1: SAVE SPACE BY AVOIDING DUPLICATION OF INFORMATION

```
type Address_Type is
record
    Street_Part : String (1 .. 25);
    City_Part   : String (1 .. 15);
    State_Part  : State_Type;
    Zip_Code_Part : Integer range 0 .. 99999;
end record;
```

```
type Person_Type is
record
    Name_Part      : String (1 .. 30);
    Residence_Part : Address_Type;
    Mailing_Address_Part : Address_Type;
    Phone_Number_Part : String (1 .. 10);
end record;
```

ALTERNATIVELY:

```
type Address_Pointer_Type is access Address_Type;
```

```
type Person_Type is
record
    Name_Part      : String (1 .. 30);
    Residence_Part : Address_Pointer_Type;
    Mailing_Address_Part : Address_Pointer_Type;
    Phone_Number_Part : String (1 .. 10);
end record;
```

EITHER WAY, PERSON P'S STATE OF RESIDENCE IS P.Residence\_Part.State\_Part



## INSTRUCTOR NOTES

THIS SLIDE ILLUSTRATES HOW THE USE OF ACCESS VALUES SAVES SPACE.

WHEN SOMEONE HAS DIFFERENT RESIDENCE AND MAILING ADDRESSES, COMPONENTS OF HIS Person\_Type RECORD WILL POINT TO TWO SEPARATE Address\_Type RECORDS; BUT IN THE USUAL CASE (EXEMPLIFIED BY JANE SMITH), TWO COMPONENTS OF THE Person\_Type RECORD POINT TO THE SAME Address\_Type RECORD, AND ADDRESS INFORMATION IS ONLY REPRESENTED ONCE.

# 1. USE OF ACCESS VALUES TO PROVIDE ACCESS TO SHARED DATA (Continued)

ILLUSTRATION OF SPACE SAVINGS

ORIGINAL METHOD	
"John Doe"	"123 Main Street"
"Waltham"	"
MA	
02154	
"P.O. Box 999"	"
"Cambridge"	"
MA	
02138	
"6172345678"	
"Jane Smith"	"100 3rd Street"
"Falls Church"	"
VA	
22041	
"100 3rd Street"	"
"Falls Church"	"
VA	
22401	
"7033456789"	

METHOD USING ACCESS TYPES	
"Jane Smith"	"100 3rd Street"
"Falls Church"	"
VA	
22041	
"John Doe"	"123 Main Street"
"Waltham"	"
MA	
02154	
"P.O. Box 999"	"
"Cambridge"	"
MA	
02138	
"6172345678"	

## INSTRUCTOR NOTES

IN ESSENCE, Ada REQUIRES ALL COMPONENTS OF AN ARRAY TO HAVE THE SAME LENGTH.

## 2. USE OF ACCESS VALUES TO BUILD RAGGED ARRAYS

A "RAGGED ARRAY" IS ONE WHICH ITSELF CONTAINS ARRAYS OF DIFFERENT LENGTHS.

THE FOLLOWING IS ILLEGAL:

```
type Name_List_Type is array (Positive range <>) of String;  
Beatles : Name_List_Type (1..4) :=  
    ("John", "Paul", "George", "Ringo");
```

-- THIS IS NOT AN EMBEDDED APPLICATION

'J'	'O'	'h'	'n'
'P'	'a'	'u'	'l'
'G'	'e'	'o'	'r'
'R'	'i'	'n'	'g'
		'o'	'e'

REASON:

STRING IS AN UNCONSTRAINED ARRAY TYPE. THE DECLARATION OF

Name\_List\_Type MUST THEREFORE SPECIFY AN INDEX CONSTRAINT FOR ITS COMPONENTS.

**INSTRUCTOR NOTES**

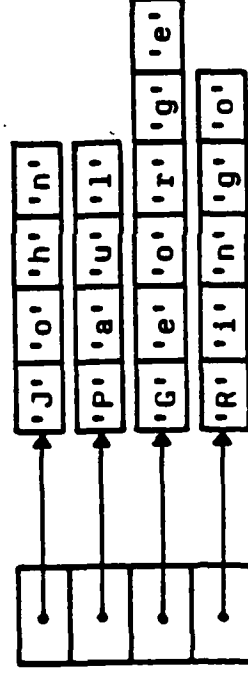
NOW THE ARRAY COMPONENTS ARE ACCESS VALUES. EVEN THOUGH THEY POINT TO STRINGS OF VARIOUS LENGTHS, THE COMPONENTS THEMSELVES ARE ALL THE SAME SIZE.

## 2. USE OF ACCESS VALUES TO BUILD RAGGED ARRAYS

### (Continued)

#### THE FOLLOWING IS LEGAL:

```
type String_Pointer_Type is access String;  
type Name_List_Type is  
  array (Positive range <>) of String_Pointer_Type;  
  
Beatles : Name_List_Type (1 .. 4) :=  
  (new String_T("John"),  
   new String_T("Paul"),  
   new String_T("George"),  
   new String_T("Ringo"));
```



## INSTRUCTOR NOTES

THE MOST EFFICIENT WAY TO DO THIS IS TO PLACE THE TANK STATUS RECORDS IN AN ARRAY AND SORT THE ARRAY ACCORDING TO THE DISTANCE OF EACH TANK FROM THE SPECIFIED POINT.

THIS SLIDE SHOWS THE SPECIFICATION OF A PROCEDURE TO DO THIS. Sort\_By\_Distance REARRANGES THE COMPONENTS OF THE ARRAY Tanks IN ORDER OF DISTANCE FROM THE POINT Reference\_Point.

### 3. USE OF ACCESS VALUES TO AVOID MOVING LARGE AMOUNTS OF DATA

EXAMPLE: A SET OF LARGE RECORDS, EACH CONTAINING STATUS INFORMATION ABOUT A TANK. THIS INFORMATION INCLUDES THE CURRENT LOCATION OF THE TANK. THE RECORDS ARE TO BE PROCESSED IN ORDER OF THE TANKS' PROXIMITY TO A GIVEN LOCATION (CLOSEST TANK FIRST).

APPROACH 1:

```
type Tank_Status_Type is
  record
    ...
    Location_Part : Location_Type;
    ...
  end record;

type Tank_Status_List_Type is
  array (Positive range <>) of Tank_Status_Type;

procedure Sort_By_Distance (Tanks      : in out Tank_Status_List_Type;
                           Reference_Point : in Location_Type);
```



## INSTRUCTOR NOTES

THE ALTERNATIVE IS TO DEFINE Tank\_Status\_List\_Type VALUES TO BE ARRAYS OF POINTERS TO RECORDS, RATHER THAN ARRAYS OF RECORDS.

THEN Tanks (1).Location\_Part REFERS TO A COMPONENT OF THE RECORD POINTED TO BY Tanks (1) RATHER THAN A COMPONENT OF Tanks (1).

IN MOST IMPLEMENTATIONS, ACCESS VALUES ARE SMALL AND ACCESS VALUE ASSIGNMENTS ARE QUITE FAST.

### 3. USE OF ACCESS VALUES TO AVOID MOVING LARGE AMOUNTS OF DATA (Continued)

#### APPROACH 2:

```
type Tank_Status_Pointer_Type is
  access_Tank_Status_Type;

type Tank_Status_List_Type is
  array (Positive range <>) of Tank_Status_Pointer_Type;

procedure Sort_By_Distance (Tanks      : in out Tank_Status_List_Type;
                             Reference_Point : in Location_Type);

-- ACCESS VALUES ARE SORTED IN ORDER OF DISTANCE FROM THE REFERENCE POINT
-- OF THE TANKS WHOSE RECORDS THEY POINT TO.
```

ADVANTAGE: WHEN Sort\_By\_Distance EXCHANGES TWO COMPONENTS OF A  
Tank\_Status\_List\_Type ARRAY, IT MOVES ACCESS VALUES INSTEAD OF LARGE  
RECORD VALUES.

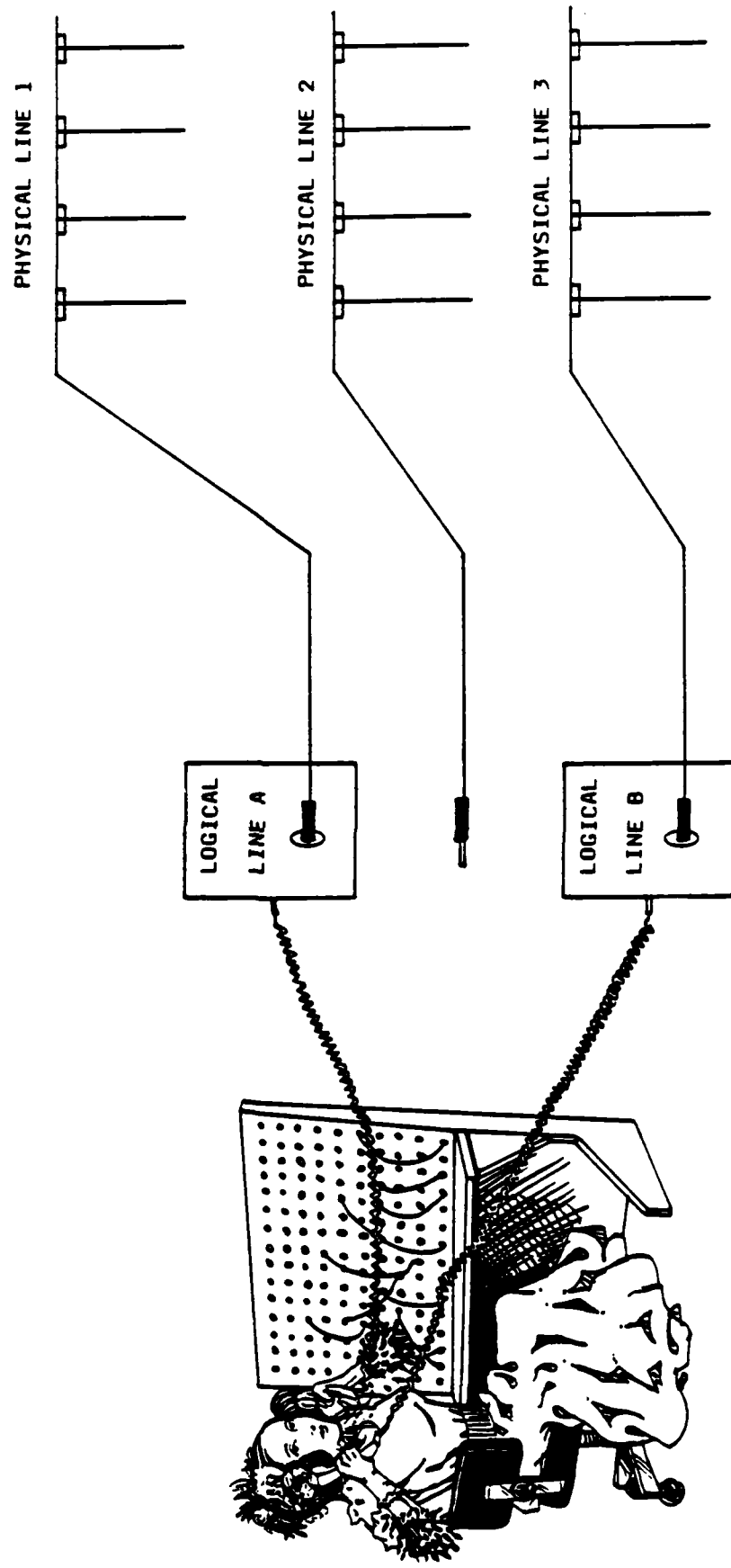
## INSTRUCTOR NOTES

A LOGICAL LINE IS ANALOGOUS TO A PHONE NUMBER, A PHYSICAL LINE TO THE WIRE CONNECTED TO THAT PHONE NUMBER.

A MESSAGE SWITCH DETERMINES DYNAMICALLY WHEN A PHYSICAL LINE IS TO PLAY THE ROLE OF TRANSMITTING MESSAGES ADDRESSED TO A GIVEN LOGICAL LINE.

USE THE FOLLOWING SLIDE FOR A GRAPHIC REPRESENTATION.

## 4. USE OF ACCESS VALUES TO CHANGE, AT RUNTIME, THE VARIABLES ASSOCIATED WITH THE NAME





## 4. USE OF ACCESS VALUES TO CHANGE, AT RUNTIME, THE VARIABLES ASSOCIATED WITH THE NAME (Continued)

EXAMPLE: A MESSAGE SWITCH

ABSTRACT VIEW: A MESSAGE IS SENT OVER ONE OF A FIXED SET OF "LOGICAL  
LINES."

IMPLEMENTATION: MESSAGES ADDRESSED TO A GIVEN LOGICAL LINE MAY BE SENT  
OVER ANY OF SEVERAL "PHYSICAL LINES" AT DIFFERENT  
TIMES. AT ANY ONE TIME, THERE IS ONE PHYSICAL LINE  
PLAYING THE ROLE OF A GIVEN LOGICAL LINE.

THE MESSAGE SWITCH MUST MAINTAIN STATUS INFORMATION ABOUT EACH LOGICAL LINE (E.G.,  
THE "NAME" OF THE LINE AND THE MESSAGE IT IS CURRENTLY TRANSMITTING) AND EACH  
PHYSICAL LINE (E.G., WHETHER THE LINE IS WORKING, HOW NOISY THE LINE IS, AND THE  
DEVICE ADDRESS OF THE LINE).



# 4. USE OF ACCESS VALUES TO CHANGE, AT RUNTIME, THE VARIABLES ASSOCIATED WITH THE NAME (Continued)

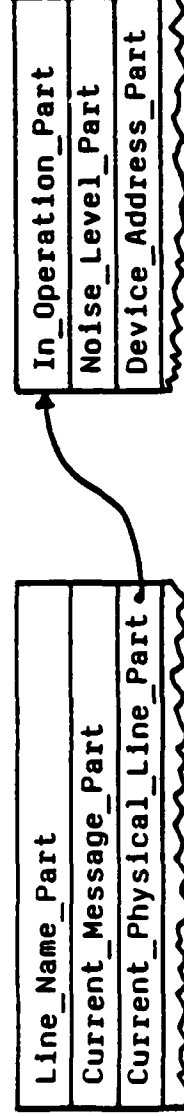
```

type Physical_Line_Status_Type is
record
    In_Operation_Part    : Boolean;
    Noise_Level_Part     : Noise_Level_Type;
    Device_Address_Part  : Device_Address_Type;
    ...
end record;

type Physical_Line_Pointer_Type is access Physical_Line_Status_Type;

type Logical_Line_Status_Type is
record
    Line_Name_Part       : Logical_Line_Name_Type;
    Current_Message_Part : Message_Type;
    Current_Physical_Line_Part : Physical_Line_Pointer_Type;
    ...
end record;

```



MESSAGES ADDRESSED TO LOGICAL LINE X ARE TRANSMITTED USING THE DEVICE ADDRESS X.Current\_Physical\_Line\_Part.Device\_Address\_Part.

REASSIGNING PHYSICAL LINES REQUIRES ONLY ACCESS VALUE ASSIGNMENTS.

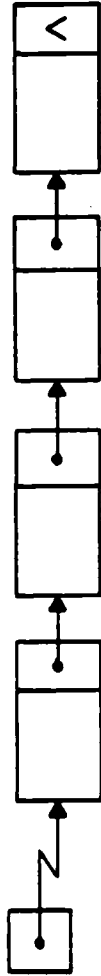


INSTRUCTOR NOTES

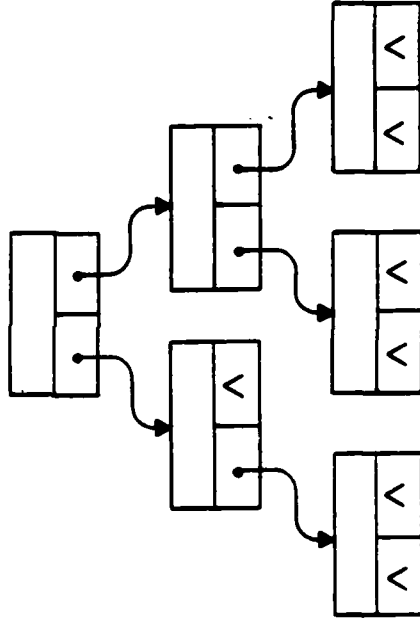
USE THIS SLIDE TO PRESENT THE IDEA OF RECURSIVE DATA TYPES. THE TOPIC WILL BE COVERED  
IN L305.

## 5. USE OF ACCESS VALUES TO DEFINE A DATA TYPE WHOSE OBJECT REFERS TO OTHER OBJECTS OF THE SAME TYPE

LINKED LIST:



BINARY TREE:



INSTRUCTOR NOTES

THIS IS THE FIRST OF THREE FORMS FOR DYNAMICALLY ALLOCATING RECORD OBJECTS WITH DISCRIMINANTS.

WHILE THE ALLOCATED OBJECT IS CONSTRAINED THE ACCESS OBJECT MAY POINT TO OTHER ALLOCATED OBJECTS HAVING DIFFERENT DISCRIMINANT VALUES. THIS WILL BE SHOWN WHEN DISCUSSING THE SECOND FORM.

# DYNAMIC ALLOCATION OF RECORDS WITH DISCRIMINANTS - FIRST FORM

NEW

RECORD TYPE NAME

- ONLY ALLOWED IF DISCRIMINANTS HAVE DEFAULT INITIAL VALUES
- ALLOCATES A RECORD OBJECT
  - DISCRIMINANTS ARE GIVEN THEIR DEFAULT INITIAL VALUES
  - NO INITIAL VALUES SPECIFIED FOR OTHER COMPONENTS
- THE ALLOCATED RECORD OBJECT IS CONSTRAINED

INSTRUCTOR NOTES

THE DISCRIMINANT HAS A DEFAULT INITIAL VALUE, SO THE ALLOCATION IS VALID.

# EXAMPLE

```
type Aircraft_Identification_Type is
  (Civilian_Aircraft, Military_Aircraft, Enemy_Aircraft, Unknown_Aircraft);
type Threat_Level_Type is (Low_Threat, Medium_Threat, High_Threat);
type Aircraft_Type (Aircraft_Identification: Aircraft_Identification_Type :=
  Unknown_Aircraft) is
  record
    Tracking_Data_Part: Tracking_Data_Type;
    case Aircraft_Identification is
      when Civilian_Aircraft =>
        null;
      when Military_Aircraft =>
        Description_Part : Description_Type;
        when Enemy_Aircraft | Unknown_Aircraft =>
          Threat_Level_Part : Threat_Level_Type;
        end case;
    end record;

  type Aircraft_Pointer_Type is access Aircraft_Type;
  Aircraft_Pointer : Aircraft_Pointer_Type;

  ...

  Aircraft_Pointer := new Aircraft_Type;
  -- Aircraft_Pointer.all is a constrained record object
```

INSTRUCTOR NOTES

THE DISCRIMINANT DOES NOT HAVE A DEFAULT INITIAL VALUE, SO THE ALLOCATION IS ILLEGAL,  
SINCE THERE IS NO WAY TO DETERMINE A VALUE FOR THE DISCRIMINANT.

# EXAMPLE

```
type Varying_String_Type (Maximum_Length: Positive) is
  record
    Current_Length : Natural;
    Contents       : String (1 .. Maximum_Length);
  end record;

type Varying_String_Pointer_Type is access Varying_String_Type;

Line: Varying_String_Pointer_Type;

...

Line:= new Varying_String_Type;
      -- Illegal since discriminant does not have default initial value
```



**INSTRUCTOR NOTES**

THIS SLIDE DISCUSSES THE SECOND OF THE TWO FORMS FOR DYNAMICALLY ALLOCATING RECORD OBJECTS WITH DISCRIMINANTS.

NOTE THAT THE AGGREGATE SIMPLIFICATION EXAMPLE ALSO SHOWS HOW TO ALLOCATE A RECORD OBJECT IN A TYPE WHOSE DISCRIMINANTS DO NOT HAVE DEFAULT INITIAL VALUES.

# DYNAMIC ALLOCATION OF RECORDS WITH DISCRIMINANTS - SECOND FORM

new RECORD TYPE NAME ( EXPRESSION )

EXPRESSION MUST BELONG TO TYPE SPECIFIED BY RECORD TYPE NAME

ALLOCATES A RECORD OBJECT

- VALUE OF RECORD OBJECT IS SPECIFIED BY EXPRESSION

- DISCRIMINANT VALUES OBTAINED FROM EXPRESSION

THE ALLOCATED OBJECT IS CONSTRAINED

EXPRESSION IS AN AGGREGATE SO COULD WRITE

Line := new Varying\_String\_Type' ((Maximum\_Length => 64));

BUT Ada ALLOWS THIS TO BE WRITTEN SIMPLY AS

Line := new Varying\_String\_Type'(Maximum\_Length => 64);

# INSTRUCTOR NOTES

THIS EXAMPLE SHOWS THAT A RECORD TYPE HAVING DEFAULT INITIAL VALUE FOR ITS DISCRIMINANTS MAY BE ALLOCATED USING EITHER FORM.

NOTE THAT ONLY THE ALLOCATED OBJECTS ARE CONSTRAINED. THE ACCESS VARIABLE `Second_Sensor_Reading` MAY POINT TO AN OBJECT WHOSE DISCRIMINANT VALUE IS TRUE OR FALSE.

## EXAMPLE

```
type Sensor_Reading_Type (Valid : Boolean := False) is
record
  case Valid is
    when True =>
      Reading_Part : Integer;
    when False =>
      null;
  end case;
end record;

type Sensor_Reading_Pointer_Type is access Sensor_Reading_Type;

Invalid_Reading : Sensor_Reading_Pointer_Type := new Sensor_Reading_Type;

First_Sensor_Reading, Second_Sensor_Reading : Sensor_Reading_Pointer_Type;

...

Second_Sensor_Reading := Sensor_Reading_Type'(Valid => True, Reading_Part => 0);
-- Second_Sensor_Reading.all is constrained

Second_Sensor_Reading := First_Sensor_Reading;

First_Sensor_Reading := Invalid_Reading;
```

INSTRUCTOR NOTES

THIS SLIDE DISCUSSES THE THIRD FORM FOR DYNAMICALLY ALLOCATING RECORD OBJECTS IN RECORD  
TYPE WITH DISCRIMINANTS.

AT THE END OF THIS SECTION RESTRICTIONS ON DISCRIMINANT CONSTRAINTS WILL BE GIVEN.

# DYNAMIC ALLOCATION OF RECORDS WITH DISCRIMINANTS - THIRD FORM

NEW

RECORD TYPE NAME

DISCRIMINANT CONSTRAINT

RECORD TYPE NAME MUST BE AN UNCONSTRAINED RECORD TYPE

ALLOCATES A RECORD OBJECT

DISCRIMINANTS ARE GIVEN THE INITIAL VALUES SPECIFIED IN

DISCRIMINANT CONSTRAINT

NO INITIAL VALUES ARE SPECIFIED FOR OTHER COMPONENTS

THE ALLOCATED OBJECT IS CONSTRAINED



## EXAMPLE

```
type Varying_String_Type (Maximum_Length : Positive) is
  record
    Current_Length : Natural;
    Contents       : String (1 .. Maximum_Length);
  end record;

type Varying_String_Pointer_Type is access Varying_String_Type;

Line : Varying_String_Pointer_Type;

Line_40 : Varying_String_Type (40);

...

Line := new Varying_String_Type (40);

Line.all := Line_40;
```



INSTRUCTOR NOTES

ALLOCATE 3 HOURS OF LECTURE FOR THIS SECTION.

ASSIGN EXERCISES 25 AND 26 OF THE EXERCISE BOOKLET FOR LAB ASSIGNMENTS.

THE OBJECTIVE OF THIS SECTION IS TO REVIEW AND FORMALIZE PROGRAM STRUCTURE, INTRODUCE FORMAL AND ACTUAL PARAMETERS, AND INTRODUCE THE CONCEPT OF SEPARATE COMPILATION.

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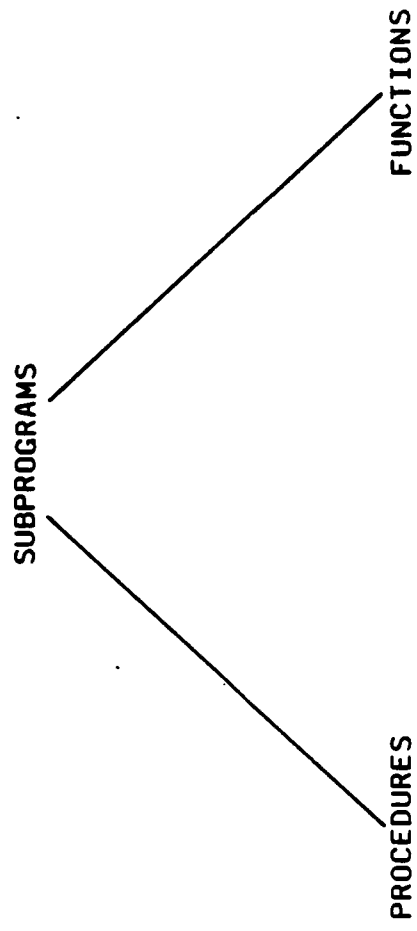
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# **SECTION 11**

## **PROGRAM STRUCTURE AND SEPARATE COMPILATION**

# INSTRUCTOR NOTES

"PROCEDURES ARE INVOKED BY PROCEDURE CALL STATEMENTS. FUNCTIONS ARE INVOKED WHEN AN EXPRESSION CONTAINING A FUNCTION CALL IS EVALUATED. FUNCTIONS RETURN VALUES, BUT PROCEDURES DON'T."



INSTRUCTOR NOTES

"MORE RIGOROUS FOR TYPE CHECKING."

# SUBPROGRAMS

- ENABLE PROGRAMMERS TO MODULARIZE PROGRAMS
- ENHANCE SOFTWARE READABILITY
- ENHANCE SOFTWARE MAINTAINABILITY
- ANALOGOUS TO THE FORTRAN SUBROUTINES AND FUNCTIONS, HOWEVER, MORE RIGOROUS

INSTRUCTOR NOTES

POINT OUT THE DISTINCTION BETWEEN WHAT SOMETHING DOES AND HOW IT IS DONE.

# SUBPROGRAMS

- PROVIDE AN ABSTRACT NAME FOR SOME ALGORITHM OR COMPUTATION
- SEPARATE THE IMPLEMENTATION OF THE ALGORITHM FROM THE SPECIFICATION OF ITS INTERFACE
- AVOID DUPLICATION OF CODE EXECUTED IN MORE THAN ONE PLACE



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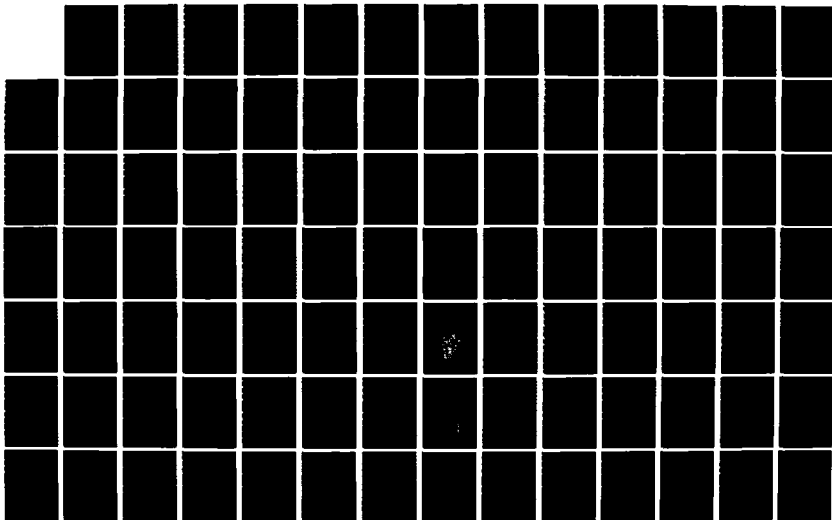
ADA (TRADE NAME) TRAINING CURRICULUM BASIC ADA  
PROGRAMMING L202 TEACHER'S GUIDE VOLUME 2(U) SOFTECH  
INC WALTHAM MA 1986 DAAB07-83-C-K514

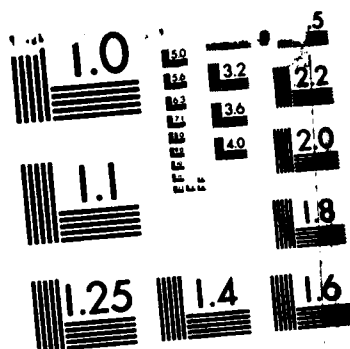
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NATIONAL BUREAU OF STANDARDS-1963-A

## INSTRUCTOR NOTES

REMIND THE STUDENTS THAT A PROCEDURE IS A SUBPROGRAM.

QUESTION: CAN THE PARAMETER LIST BE LEFT OUT?

ANSWER: YES IF THE FORMAL PARAMETERS HAVE DEFAULT VALUES. (THESE WILL BE COVERED LATER) OR IF THE SUBPROGRAM DOES NOT NEED PARAMETERS.

# PROCEDURE

- DEFINES A SEQUENCE OF ACTIONS
- IS INVOKED WITH A PROCEDURE CALL
- A PROCEDURE CALL IS A STATEMENT. THE STATEMENT LOOKS LIKE

Procedure\_Name [( Parameter\_List )];

INSTRUCTOR NOTES

EXPLAIN THAT A PROCEDURE CALL CAN OCCUR ANYWHERE A STATEMENT CAN (E.G. AFTER THE THEN IN AN IF STATEMENT).

# PROCEDURE CALL EXAMPLE

```
with Text_IO; use Text_IO;
with Vector_Services; use Vector_Services;
procedure Compute_Tracking_Data Is
```

```
    Last_Point, Current_Point : Point_Type;
```

```
    Time                       : Time_Type;
```

```
    Velocity                   : Float;
```

```
    ...
```

```
begin -- Compute_Tracking_Data
```

```
    ...
```

```
    Calculate_Velocity (Last_Point, Current_Point, Time, Velocity);
```

```
    ...
```

```
end Compute_Tracking_Data;
```

procedure

call



INSTRUCTOR NOTES

POINT OUT OR HIGHLIGHT NON OPTIONAL PARTS OF A PROCEDURE BODY. I.E. THE begin IS NOT  
OPTIONAL.

# PROCEDURES

## GENERAL FORM OF A PROCEDURE BODY

```
procedure Procedure_Name [(Parameter_List : [mode] Parameter_Type
                           {; Parameter_List : [mode] Parameter_Type})] is
    -- local declarations (if any)
begin
    -- Procedure_Name
    -- local statements
    -- may OPTIONALLY include one or more return statements:
    [return;]
    -- to terminate execution of procedure body and return to caller
end Procedure_Name;
```



# INSTRUCTOR NOTES

## FOR THE 3 MODES

- in CALLER PASSES VALUE TO CALLED
- out CALLED PASSES VALUE TO CALLER
- in out CALLER PASSES VALUE TO AND ACCEPTS VALUE FROM CALLED.

# PARAMETERS

PARAMETERS PROVIDE THE MEANS THROUGH WHICH INFORMATION OR DATA IS TRANSFERRED BETWEEN THE CALLED SUBPROGRAM AND ITS CALLER. THIS TRANSFER MAY WORK IN THE FOLLOWING DIRECTIONS:

CALLER -----> CALLED  
CALLER <----- CALLED  
CALLER <----> CALLED

THE PARAMETER MODE SPECIFIES WHICH DIRECTIONS ARE ALLOWED:

in  
out  
in out  
(no mode specified) -- equivalent to in

## INSTRUCTOR NOTES

1. "out and in out parameters must be some object that could appear on the left-hand side of an assignment (i.e., a variable)."

2. A curious fact about out parameters with which to dazzle and confuse the class:

if the called subprogram doesn't update the value of an out parameter, the value is undefined (even if it was previously defined), e.g.:

```
.
.
.
A := 5.2;
Grunt (A);
-- value of A is now
-- undefined (unless
-- Today is Tuesday)
.
.
.
```

```
procedure Grunt (X : out Float) is
  if Today = Tuesday
  then
    X := 2.3;
  end if;
end Grunt;
```

3. out parameters are write only. you cannot read the value of an out parameter inside the procedure.

```
procedure P (X : out Integer) is
begin -- P
  X := 6;
  if X > 3 then -- ILLEGAL
    null;
  end if;
end P;
```

# PARAMETER MODES

in (CALLER ----->CALLED)

- ACT AS LOGICAL INPUTS
- ACT AS A CONSTANT AND MAY NOT BE UPDATED
- THIS MODE ASSUMED IF in IS NOT EXPLICITLY STATED

THUS THE CALLED SUBPROGRAM CANNOT RETURN ANY VALUE THROUGH THE in  
PARAMETER TO THE CALLER

out (CALLER <----- CALLED)

- ACT AS LOGICAL OUTPUTS

THUS THE CALLED SUBPROGRAM CANNOT RECEIVE ANY INFORMATION OR DATA  
FROM THE CALLER THROUGH AN out PARAMETER. THE CALLED SUBPROGRAM CAN,  
HOWEVER, PASS DATA BACK TO THE CALLER BY ASSIGNING A VALUE TO THE out  
PARAMETER.

in out (CALLER <-----> CALLED)

- ACT AS VARIABLES WHOSE VALUES MAY BE UPDATED DURING  
EXECUTION OF THE PROCEDURE

THUS THE CALLED SUBPROGRAM BOTH RECEIVES DATA FROM THE CALLER AND PASSES  
DATA BACK TO THE CALLER THROUGH THE in out PARAMETER

INSTRUCTOR NOTE

REMIND STUDENTS THAT IN PARAMETERS ACT AS LOCAL CONSTANTS.

## A TYPICAL ERROR

```
with Text_IO; use Text_IO;
procedure This_Open (Name : in File_Type) is
begin -- This_Open
    Create (Name, Out_File, "Data.dat"); -- ** ILLEGAL
end This_Open;
```

- NAME IS A PARAMETER OF MODE "in"
- CREATE EXPECTS PARAMETER OF MODE "in out"
- ERROR MESSAGE GENERATED INDICATES PARAMETER NO. 1 IN CALL IS NOT A VARIABLE

# INSTRUCTOR NOTES

"BASICALLY ANYTHING YOU ARE NOT ALLOWED TO ASSIGN TO NORMALLY CANNOT BE PASSED TO AN OUT  
OR IN OUT FORMAL PARAMETER."

TO EXPLAIN "PARAMETER TO FUNCTIONS"

procedure Example (X : Integer) is

procedure P(I : in out Integer) is

begin -- P

null;

end P;

begin -- Example

P (X); -- ILLEGAL

end Example;

# NOTES

SOME OBJECTS CAN ONLY BE PASSED AS in MODE PARAMETERS,  
NAMELY THOSE OBJECTS ONE CANNOT ASSIGN TO:

- CONSTANTS
- in PARAMETERS OF THE CALLING SUBPROGRAM
- LOOP PARAMETERS OF A "for" LOOP
- DISCRIMINANTS



INSTRUCTOR NOTES

POINT OUT THAT THE VALUE RETURNED CAN BE A VALUE OF A COMPOSITE TYPE.

# FUNCTION

- DEFINES A COMPUTATION WHICH RETURNS A VALUE
  - VALUE MAY BE OF ANY TYPE (E.G., ARRAY OR RECORD)
  - TERMINATES UPON EXECUTION OF A RETURN STATEMENT
- IS INVOKED WITH A FUNCTION CALL WITHIN AN EXPRESSION
- SYNTAX OF A FUNCTION CALL IS  
Function\_Name [( Parameter\_List )]

INSTRUCTOR NOTES

POINT OUT THAT A FUNCTION CALL IS NOT A STATEMENT. THEREFORE A LOCAL VARIABLE IS REQUIRED TO CAPTURE THE VALUE RETURNED BY THE FUNCTION.

## FUNCTION CALL EXAMPLE

```
with Text_IO; use Text_IO;
with Vector_Services; use Vector_Services;
procedure Compute_Tracking_Data Is

    Last_Point, Current_Point : Point_Type;
    Distance                   : Float;

    ...

begin -- Compute_Tracking_Data

    ...

function call → Distance := Distance_Between (Last_Point, Current_Point);

    ...

end Compute_Tracking_Data;
```

INSTRUCTOR NOTES

POINT OUT (HIGHLIGHT) NON-OPTIONAL ITEMS.

POINT OUT THAT THE PARAMETER MODE MUST BE `in`. (SUGGESTED CONVENTION: WRITE `in` EXPLICITLY FOR PROCEDURES, OMIT IT FOR FUNCTIONS.)

EXPLAIN THAT THE RETURN CLAUSE IN THE SPECIFICATION DEFINES THE TYPE OF THE VALUE RETURNED. THE RETURN STATEMENT IN THE BODY RETURNS THE ACTUAL VALUE.

# FUNCTIONS

## GENERAL FORM OF A FUNCTION BODY

```
function Function_Name [( Parameter_List : [in] Parameter_Type
    ( ; Parameter_List : [in] Parameter_Type ) ) ] return Type_Name is
    -- local declarations (if any)
begin
    -- Function_Name
    -- local statements
    -- MUST include at least one return statement:
    -- the return statement terminates execution of the subprogram
    -- and specifies the value to be returned
    return Value; -- where Value is of type Type_Name
end Function_Name;
```



# EXAMPLE

```
separate (Vector Services)
function Next_Point_After (Last_Point, This_Point : in Point_Type;
    Time_Between_Last, Time_Between_Next : Time_Type)
    return Point_Type is

    Next_Point : Point_Type;

begin -- Next_Point_After

    if Time_Between_Last = 0 then
        return This_Point;
    else
        Next_Point(X) := Last_Point(X) + Float(Time_Between_Next/Time_Between_Last)
            * abs (This_Point(X) - Last_Point(X));
        Next_Point(Y) := Last_Point(Y) + Float(Time_Between_Next/Time_Between_Last)
            * abs (This_Point(Y) - Last_Point(Y));
        return Next_Point;
    end if;

end Next_Point_After;
```



INSTRUCTOR NOTES

JUST ANOTHER EXAMPLE. DISCUSS

- STRUCTURE
- TYPE CONVERSION

## ANOTHER EXAMPLE

### CONTEXT:

```
type Scores_Type is digits 5 range 0.0 .. 100.0;
type List_Type is array (1 .. 15) of Scores_Type;
```

### EXAMPLE:

```
function Mean (List : in List_Type) return Scores_Type is
    Sum : Scores_Type := 0.0;

begin -- Mean
    for I in List'Range loop
        Sum := Sum + List (I);
    end loop;

    return Sum / Scores_Type (List'Last);

end Mean;
```

## INSTRUCTOR NOTES

"WE MAY CONSIDER A SUBPROGRAM TO HAVE ITS OWN SET OF INTERNAL VARIABLES WHICH IT USES IN ITS CALCULATIONS. THESE ARE THE FORMAL PARAMETERS. THE ACTUAL PARAMETERS ARE USED ONLY UPON ENTRY TO THE SUBPROGRAM (WHEN VALUES ARE COPIED FROM ACTUAL TO FORMAL in AND in out PARAMETERS) AND UPON EXIT (WHEN VALUES ARE COPIED FROM FORMAL TO ACTUAL out AND in out PARAMETERS)." ."

POINT OUT THAT FORMAL PARAMETERS ARE SEPARATED BY SEMICOLONS. ACTUAL PARAMETERS ARE SEPARATED BY COMMAS.

# FORMAL AND ACTUAL PARAMETERS

- THE PARAMETERS LISTED IN THE SUBPROGRAM SPECIFICATION ARE CALLED THE FORMAL PARAMETERS. THOSE SPECIFIED IN THE SUBPROGRAM CALL ARE KNOWN AS THE ACTUAL PARAMETERS.
- WHEN THE SUBPROGRAM IS CALLED EACH ACTUAL PARAMETER IS ASSOCIATED WITH A FORMAL PARAMETER. THE TYPE OF THE ACTUAL PARAMETER MUST MATCH THE TYPE OF THE FORMAL PARAMETER.

## INSTRUCTOR NOTES

POINT OUT THAT THE SPECIFICATION MAY BE TERMINATED BY A ";" IF IT IS A DECLARATION OR IT MAY BE FOLLOWED BY THE WORD "is" TO INDICATE THAT THE BODY FOLLOWS.

POINT OUT THAT ALL THE CONTEXT IS NOT NECESSARY HERE. THE IDEA IS TO DISTINGUISH BETWEEN FORMAL PARAMETERS AND ACTUAL PARAMETERS.

POINT OUT THIS IS A PROCEDURE.

# EXAMPLES

## SPECIFICATION:

```
procedure Calculate_Velocity (From, To      : in Point_Type;  
                             In_Time       : in Time_Type;  
                             At_Velocity  : out Float)
```

## CALL:

```
Calculate_Velocity (Last_Pt, This_Pt, Time, Velocity);
```

FORMALS:	From	To	In_Time	At_Velocity
----------	------	----	---------	-------------

ACTUALS:	Last_Pt	This_Pt	Time	Velocity
----------	---------	---------	------	----------

INSTRUCTOR NOTES

THIS IS FOR A FUNCTION.

## ANOTHER EXAMPLE

### SPECIFICATION:

function Distance\_Between (Point\_A, Point\_B : in Point\_Type) return Float;

### CALL:

Distance := Distance\_Between (Last\_Pt, This\_Pt);

FORMALS:      Point\_A    Point\_B

ACTUALS:      Last\_Pt    This\_Pt



INSTRUCTOR NOTES

POINT OUT THAT THESE ARE ALTERNATIVE NOTATIONS.

# ACTUAL PARAMETERS

## POSITIONAL NOTATION:

PARAMETERS MUST BE LISTED IN THE SAME ORDER AS THE FORMAL PARAMETERS

## NAMED NOTATION:

THERE IS AN EXPLICIT ASSOCIATION BETWEEN THE FORMAL AND ACTUAL  
PARAMETERS



# EXAMPLE

## SPECIFICATION:

```
procedure Calculate_Velocity (From, To : in Point_Type;  
    In_Time : in Time_Type;  
    At_Velocity : out Float)
```

## CALL:

### POSITIONAL

```
Calculate_Velocity (Last_Pt, This_Pt, Time, Velocity);
```

### NAMED

```
Calculate_Velocity (From => Last_Pt, To => This_Pt,  
    In_Time => Time, At_Velocity => Velocity);
```



## EXAMPLES

### SPECIFICATION:

```
function Distance_Between (Point_A, Point_B : in Point_Type) return Float;
```

### CALL:

#### POSITIONAL

```
Distance := Distance_Between (Last_Pt, This_Pt);
```

#### NAMED

```
Distance := Distance_Between (Point_A => Last_Pt,  
                               Point_B => This_Pt);
```

**INSTRUCTOR NOTES**

**USE THIS FOIL AS A SUMMARY.**

## NOTES:

- IN NAMED NOTATION, ACTUAL PARAMETERS MAY BE SPECIFIED IN A DIFFERENT ORDER THAN THE FORMAL PARAMETER LIST.

### EXAMPLE:

```
Calculate_Velocity (At_Velocity => Velocity,  
                   From      => Last_Pt,  
                   In_Time   => Time,  
                   To        => This_Pt);
```

- ADVANTAGES OF NAMED NOTATION

- AVOIDS ERRORS IN PARAMETER POSITION (THE CAUSE OF INSIDIOUS PROGRAM BUGS)
- IDIOMATIC: IF FORMAL PARAMETERS ARE APPROPRIATELY NAMED THEN THE SUBPROGRAM CALL READS LIKE A SENTENCE.

### EXAMPLE:

```
Push ( Element => X, On_To => Stack);
```

- DISADVANTAGES OF NAMED NOTATION

- LENGTH: SOMETIMES DEDUCTS FROM READING THE PROCEDURE CALL AS A SINGLE ENTITY





## SOME GUIDELINES

A SUBPROGRAM REQUIRING A SMALL NUMBER (3 OR LESS) OF PARAMETERS SHOULD PROBABLY  
USE A POSITIONAL CALL UNLESS THE ORDER, IS VERY CONFUSING (LIKE A ROUTINE  
Move(A,B) WHERE THERE IS CONFUSION: DOES A MOVE TO B? OR DOES B MOVE TO A?)

[illegible]

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11-24i

176

1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

[illegible][illegible]

# OPTIONAL ARGUMENTS AND DEFAULT VALUES

- OPTIONAL ARGUMENTS OCCUR WHEN, IN THE SUBPROGRAM SPECIFICATION, A DEFAULT INITIAL VALUE IS SPECIFIED FOR ONE OR MORE PARAMETERS. FOR EXAMPLE:

```
procedure Set_Threshold (Lower: Threshold_Type := 60;  
                        Upper: Threshold_Type := 70) is
```

```
...  
begin -- Set_Threshold  
...  
end Set_Threshold;
```

- WHENEVER THE PROCEDURE Set\_Threshold IS CALLED, THE VARIABLES Lower AND Upper WILL HAVE VALUES OF 60 AND 70 RESPECTIVELY, UNLESS OTHER VALUES ARE SPECIFIED IN THE PROCEDURE CALL. IN THE FOLLOWING CALL, THE VALUE 50 OVERRIDES THE LOWER INITIAL VALUE OF 60. BECAUSE THE DEFAULT VALUE IS TO BE USED FOR Upper, IT NEED NOT BE GIVEN IN THE PARAMETER LIST:

```
Set_Threshold ( Lower => 50 );
```

- DEFAULT VALUES MAY BE GIVEN FOR IN PARAMETERS ONLY
- A SUBPROGRAM WITH OPTIONAL ARGUMENTS SHOULD USE NAMED NOTATION.

001 002 003 004 005 006 007 008 009 010 011 012 013 014 015 016 017 018 019 020 021 022 023 024 025 026 027 028 029 030 031 032 033 034 035 036 037 038 039 040 041 042 043 044 045 046 047 048 049 050 051 052 053 054 055 056 057 058 059 060 061 062 063 064 065 066 067 068 069 070 071 072 073 074 075 076 077 078 079 080 081 082 083 084 085 086 087 088 089 090 091 092 093 094 095 096 097 098 099 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 101

- VG 728.2

11-25i

# DO WE NEED BOTH DECLARATION AND BODY ?

- BOTH A DECLARATION AND BODY MAY APPEAR FOR A GIVEN SUBPROGRAM. IN THIS CASE THE SPECIFICATION IN THE BODY MUST MATCH THE SPECIFICATION IN THE DECLARATION
- ALTERNATIVELY THE BODY MAY APPEAR ALONE. IN THIS CASE THE BODY SERVES AS BOTH DECLARATION AND BODY, DEFINING BOTH THE INTERFACE WITH THE CALLER AND THE IMPLEMENTATION OF THE PROCEDURE

INSTRUCTOR NOTES

THE BODY OF Average IS IN THE BODY OF Vector\_Package.

EXAMPLE: SUBPROGRAM SPECIFICATION APPEARING IN A DECLARATION.

```
package Vector_Package is
  type Vector_Type is array (Integer range <>) of Integer;
  function Average (V : Vector_Type) return Float;
end Vector_Package;
```

EXAMPLE: SUBPROGRAM SPECIFICATION APPEARING AS PART OF THE BODY.

```
procedure Calc_Average is
  type Vector_Type is array (Integer range <>) of Integer;
  function Average (V : Vector_Type) return Float is
    Sum : Integer := 0;
  begin -- Average
    for I in V'Range
      loop
        Sum := Sum + V (I);
      end loop;
    return Float(Sum)/Float(V'Length);
  end Average;
begin -- Calc_Average
  ...
end Calc_Average;
```



INSTRUCTOR NOTES

POINT OUT THE CASES WHERE YOU WOULD WANT ONLY THE DECLARATIONS. I.E. IN PACKAGE SPECIFICATIONS AND IN SEPARATE SPECIFICATIONS.

INTRODUCE THIS IN THE FRAMEWORK OF PACKAGES. THE STUDENTS BY THE END OF THIS COURSE SHOULD UNDERSTAND WHY AND HOW TO IMPORT PACKAGES. EXPLAIN THAT SUBPROGRAM DECLARATIONS ARE ONE OF THE THINGS THEY WILL SEE THERE. OTHER THINGS ARE TYPE DECLARATIONS (SO THAT'S WHY WE'VE SPENT HOURS ON END ...)

# SPECIFICATION AND DECLARATION

- THE PART OF A SUBPROGRAM BODY PRECEDING THE WORD `is` IS CALLED A SUBPROGRAM SPECIFICATION

EXAMPLE:

```
procedure Calculate_Velocity (From, To : in Point_Type;  
    In_Time : in Time_Type  
    At_Velocity : out Float) is  
  
begin -- Calculate_Velocity  
    ...  
end Calculate_Velocity;
```

- A SUBPROGRAM DECLARATION IS A SUBPROGRAM SPECIFICATION FOLLOWED BY A SEMICOLON ("`;`"). IT DEFINES THE INTERFACE OF THE SUBPROGRAM WITH ITS CALLER

EXAMPLE:

```
procedure Calculate_Velocity (From, To : in Point_Type;  
    In_Time : in Time_Type  
    At_Velocity : out Float);
```



# PROCEDURES

## GENERAL FORM OF A PROCEDURE DECLARATION

```
procedure Procedure_Name [(Parameter_List : [mode] Parameter_Type  
    {; Parameter_List : [mode] Parameter_Type } )];
```

## INSTRUCTOR NOTES

STRESS THAT AS A GENERAL RULE THE PARAMETER MODE SHOULD BE SPECIFIED TO DICTATE ACTUAL USE OF THE PARAMETER. IN OTHER WORDS DON'T MAKE ALL PARAMETERS IN OUT JUST BECAUSE IT IS EASIER NOT TO DECIDE WHICH MODE THE PARAMETER SHOULD BE. THIS METHOD OF DESIGN WILL CAUSE PROBLEMS LATER.

# EXAMPLES

## PROCEDURE DECLARATIONS

```
procedure Find_First_RI (Message: in Message_Type; Pos: out Position;  
                        Status : out RI_Status_Type);
```

```
procedure Make_Line_Available (Physical_Line: in Physical_Line_Type);
```

```
procedure Draw_Line (Point_1, Point_2 : Point_Type);
```

```
procedure Rewind_Tape;
```

```
procedure Calculate_Median (List : in List_Type;  
                           Midpoint : out Scores_Type);
```



# FUNCTIONS

## GENERAL FORM OF A FUNCTION DECLARATION

```
function Function_Name [(Parameter_List : [in] Parameter_Type  
    {; Parameter_List : [in] Parameter_Type})] return Type_Name;
```



INSTRUCTOR NOTES

POINT OUT THAT EACH DECLARATION DEFINES A BLACK BOX ACTIVITY.

# EXAMPLES

## FUNCTION DECLARATIONS

```
function Read_Character_Count (Segment: Segment_Pointer_Type) return Natural;  
  
function Valid_Physical_Line (Logical_Line : Logical_Line_Type;  
    Physical_Line : Physical_Line_Type) return Boolean;  
  
function Read_Segment_Number (Segment: Segment_Pointer_Type) return Segment_Number;  
  
function Hardware_Clock_Reading return Hardware_Clock_Time;  
  
function Is_Line_Available (Logical_Line: Logical_Line_Type) return Boolean;  
  
function Is_Line_To_Be_Intercepted (Logical_Line : Logical_Line_Type;  
    This_Precedence : Precedence_Type;  
    This_Medium : Medium_Type) return Boolean;  
  
function Mean (List : in List_Type) return Scores_Type;
```

INSTRUCTOR NOTES

POINT OUT THAT LOCAL DATA IS NOT ACCESSIBLE FROM OUTSIDE THE SUBPROGRAM.

# LOCAL VS. GLOBAL DATA

- VARIABLES DECLARED WITHIN A SUBPROGRAM ARE KNOWN AS LOCAL VARIABLES:

procedure P is

    Local : Integer; -- local variable

begin -- P

    ...

end P;

Local only known here

- VARIABLES KNOWN WITHIN A SUBPROGRAM BUT DEFINED BY THE CALLER (INSTEAD OF LOCALLY) ARE KNOWN AS GLOBAL VARIABLES.

- ASSIGNMENT TO GLOBAL VARIABLES (SIDE EFFECTS) IS ALLOWED WITHIN BOTH FUNCTIONS AND PROCEDURES
- SUCH PRACTICES ARE FROWNED UPON: THEY ARE THE MAINTENANCE PROGRAMMER'S NIGHTMARE.
- VALUES YOU WISH TO CHANGE SHOULD BE PASSED AS in out PARAMETERS

# INSTRUCTOR NOTES

## RULE OF THUMB FOR NESTING

- 1) IF THE SUBPROGRAM IS USEFUL ONLY TO ITS PARENT, NEST IT (OR PLACE BOTH IT AND ITS PARENT IN A PACKAGE).
- 2) IF IT IS USEFUL IN SEVERAL PLACES, UNNEST IT. (WE WILL DISCUSS UNNESTING SOON).

REMEMBER NESTING ALLOWS, BUT DOES NOT REQUIRE A PROGRAM HIERARCHY.

# NESTING

SUBPROGRAM DECLARATIONS MAY BE NESTED INSIDE ANOTHER SUBPROGRAM.  
IT IS NOT RECOMMENDED TO WRITE DEEPLY NESTED SUBPROGRAMS.

## EXAMPLE:

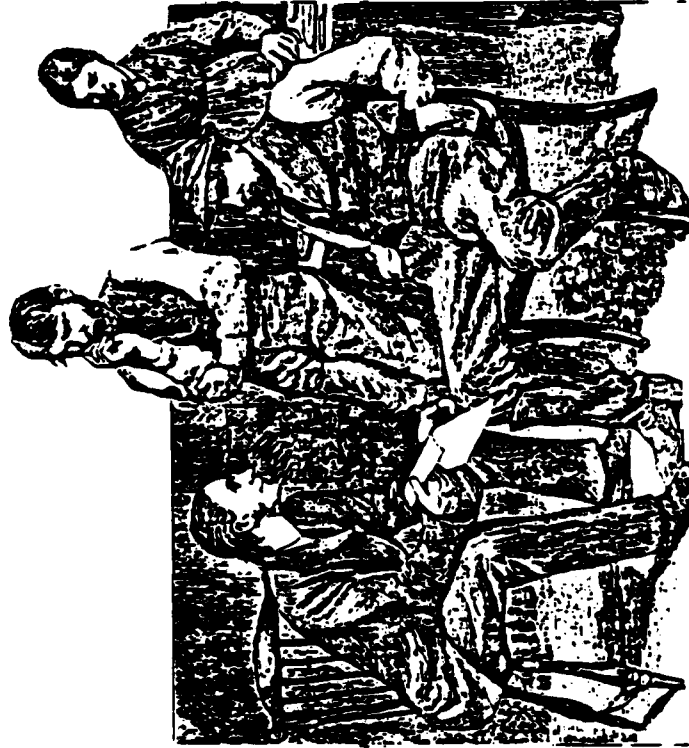
```
procedure Calculate_Median (List : in List_Type;  
                           Midpoint : out Scores_Type) is  
  Temp_List : List_Type := List;  
  ---  
  --- other local declarations  
  ---  
  procedure Sort (Some_List : in out List_Type) is  
    --  
    -- local declarations  
    --  
    begin -- Sort  
      --  
      -- the sort algorithm  
      --  
      end Sort;  
    begin -- Calculate_Median  
      Sort (Temp_List);  
      --  
      -- remaining statements to obtain median  
      --  
      end Calculate_Median;
```

## INSTRUCTOR NOTES

"RECALL THAT A PRINCIPAL GOAL OF Ada IS TO SUPPORT 'PROGRAMMING IN THE LARGE'. LARGE PROJECTS ARE UNDERTAKEN BY MANY PERSONS WORKING IN TEAMS. IT IS ESSENTIAL THAT THEY BE ABLE TO WRITE, COMPILE AND TEST MODULES INDEPENDENTLY. AT THE SAME TIME INTERFACES MUST BE WELL-DEFINED TO ENSURE COMPATIBILITY BETWEEN MODULES."

SEPARATE COMPILATION IS A DESIGN ISSUE. POINT OUT DIFFERENCES FROM PASCAL, WHERE ALL SUBPROGRAMS ARE NESTED INSIDE ONE MAIN PROGRAM.

# PROGRAMMING IN THE LARGE



TAKING ADVANTAGE OF THE POWER OF  
SEPARATE COMPILATION DEPENDS ON  
AN UNDERSTANDING OF:

- Ada COMPILATION UNIT  
STRUCTURE
- AND
- Ada COMPILATION ORDER



## INSTRUCTOR NOTES

CURRENT THOUGHTS ON PROGRAM METHODOLOGY - NEED BOTH BOTTOM-UP AND TOP-DOWN DESIGN.

Ada WAS DESIGNED TO REDUCE SOFTWARE COSTS. NEED REUSABLE SOFTWARE PACKAGES, OFF THE SHELF SOFTWARE COMPONENTS (HELPS WHEN BUILDING SYSTEM BOTTOM-UP).

# ADA PROVIDES TWO MECHANISMS FOR SEPARATE COMPILATION

- TOP-DOWN
  - LARGE COHERENT PROGRAM BROKEN DOWN INTO SEPARATELY-COMPILED SUBUNITS
  - SUBUNITS COMPILED AFTER UNIT ON WHICH THEY DEPEND
  - MECHANISM IMPLEMENTED USING "...is separate" AND "separate (...)" NOTATION
- BOTTOM-UP
  - TYPICAL APPLICATION IS A "LIBRARY" OF SUBPROGRAMS WRITTEN FOR GENERAL USE (PACKAGES)
  - THESE ARE WRITTEN BEFORE UNITS THAT USE THEM
  - UNITS THAT DEPEND ON THEM GET ACCESS VIA with AND use CLAUSES

## INSTRUCTOR NOTES

LIBRARY UNITS ARE UNITS THAT CAN BE USED IN WITH CLAUSES. SECONDARY UNITS CANNOT APPEAR IN WITH CLAUSES. USING OVERLAYING FOILS SHOW HOW TO UNNEST THE TWO FUNCTIONS ON PAGE 10-33 (ENTITLED "NESTING").

POINT OUT THAT A use CLAUSE WOULD BE ILLEGAL BECAUSE YOU CAN ONLY use PACKAGES.

# SEPARATE COMPILATION

- LARGE Ada PROGRAMS MAY BE BROKEN INTO PIECES WHICH ARE COMPILED SEPARATELY
- A COMPILATION CONSISTS OF ONE OR MORE COMPILATION UNITS WHICH ARE SUBMITTED TOGETHER TO THE Ada COMPILER
- COMPILATION UNITS INCLUDE:
  - package declarations
  - subprogram declaration
  - subprogram body
  - package body
  - subunit

INSTRUCTOR NOTES

SUBUNIT? EXCUSE ME,  
BUT I DON'T BELIEVE  
WE'VE DISCUSSED SUB-  
UNITS, HAVE WE?



INSTRUCTOR NOTES

EMPHASIZE THAT STUBBING AND SUBUNITS ARE INDIVISABLE.

POINT OUT THAT IT REPRESENTS A MECHANISM FOR TOP DOWN DEVELOPMENT OF LARGE SYSTEMS USING  
TEAMS OF PROGRAMMERS.

# SUBUNITS

- IN ADDITION TO BREAKING AN Ada PROGRAM INTO SEPARATELY COMPILED LIBRARY UNITS, ANOTHER SEPARATE COMPILE CAPABILITY IS AVAILABLE BY USING BODY STUBS AND SUBUNITS. THIS IS THE "TOP-DOWN" APPROACH.
- AT THE POINT WHERE A SUBPROGRAM BODY OR PACKAGE BODY WOULD NORMALLY APPEAR IN A COMPILATION, A BODY STUB MAY BE USED INSTEAD

```
procedure Subprogram_Name is separate;
```

THIS IMPLIES THAT THE ACTUAL BODY WILL BE SUPPLIED IN A SEPARATE SUBUNIT.
- THE BODY IS SUPPLIED WITH A PREFIX INDICATING OR NAMING THE COMPILE UNIT WHERE THE CORRESPONDING BODY STUB APPEARED

```
separate (Parent_Unit)      -- note no semicolon
procedure Subprogram_Name is -- body
```
- ALTHOUGH THE SUBUNIT IS SEPARATELY COMPILED THE EFFECT IS EXACTLY AS IF THE ACTUAL BODY WERE GIVEN AT THE POINT OF THE BODY STUB



## INSTRUCTOR NOTES

STUBBING IS USEFUL FOR TWO REASONS:

- 1)       ALLOWS PROJECTS TO BE SPLIT AMONG SEVERAL PROGRAMMERS, ALLOWING THEM TO  
          COMPILE THEIR OWN CODE.
- 2)       IT INCREASES READABILITY. NESTED SUBPROGRAMS CAN BE STUBBED OUT. ONLY THE  
          SPECIFICATIONS ARE LEFT, WHICH MAKES THE ENCLOSING PROCEDURE MORE READABLE.

# STUBBING

## NESTED

```
procedure Calculate_Median (...) is
--
-- local declarations
--
procedure Sort (...) is
--
-- local declarations
--
begin -- Sort
...
end Sort;
begin -- Calculate_Median
...
end Calculate_Median;
```

## STUB

```
procedure Calculate_Median (...) is
--
-- local declarations
--
procedure Sort (...) is separate;
begin -- Calculate_Median
...
end Calculate_Median;
```

## SUBUNIT

```
separate (Calculate_Median)
procedure Sort (...) is
...
begin -- Sort
...
end Sort;
```

## INSTRUCTOR NOTES

A PROGRAM LIBRARY IS NOT A LIBRARY OF PROGRAMS, BUT A LIBRARY FOR A PARTICULAR PROGRAM. IT CONTAINS THE DECLARATIVE INFORMATION FOUND IN THE PROGRAM'S LIBRARY UNITS, INFORMATION THAT OTHER UNITS COMPILED LATER MAY NEED ACCESS TO. THIS INCLUDES THE INFORMATION IN PACKAGE DECLARATIONS AND SUBPROGRAM DECLARATIONS. THE COMPILER DETERMINES THE LEGALITY AND MEANING OF A CALL ON A PREVIOUSLY COMPILED SUBPROGRAM, E.G., BY CONSULTING THE PROGRAM LIBRARY.

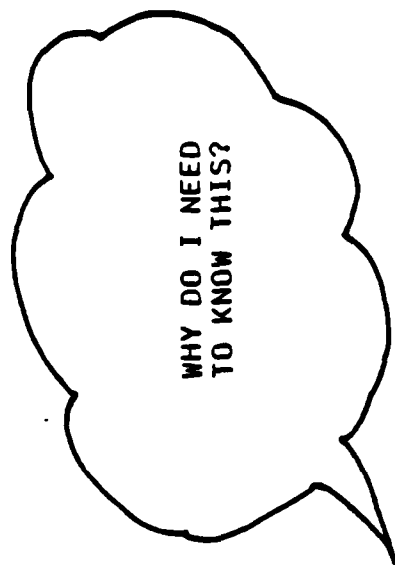
A PROGRAM LIBRARY CONTAINS DECLARATIVE INFORMATION, NOT OBJECT CODE. IT IS LIKE A SYMBOL TABLE FOR THE ENTIRE PROGRAM, BUT ONE WHICH REMAINS INTACT BETWEEN INVOCATIONS OF THE COMPILER.

# PROGRAM LIBRARY

- EVERY Ada PROGRAM HAS AN ASSOCIATED PROGRAM LIBRARY
- CERTAIN COMPILATION UNITS (PACKAGE DECLARATIONS, SUBPROGRAM DECLARATIONS, AND SUBPROGRAM BODIES WHEN THERE IS NO CORRESPONDING SUBPROGRAM DECLARATION) ARE LIBRARY UNITS
- IN ESSENCE, LIBRARY UNITS PROVIDE INTERFACE INFORMATION AND OTHER SPECIFICATION DATA NEEDED BY THE COMPILER TO PROCESS OTHER UNITS.
- AS LIBRARY UNITS ARE COMPILED, THEIR DECLARATIONS GO INTO THE PROGRAM LIBRARY
- A PROGRAM LIBRARY CONTAINS DECLARATIONS, NOT OBJECT CODE.
- THE COMPILER USES THE PROGRAM LIBRARY TO PROCESS A REFERENCE TO A PREVIOUSLY COMPILED LIBRARY UNIT.

# INSTRUCTOR NOTES

"YOU PROBABLY THINK THIS IS A GOOD QUESTION. IN REALITY YOU NEED TO KNOW THIS IN ORDER TO IMPLEMENT LARGE SYSTEMS. YOU NEED TO KNOW ABOUT COMPILATION ORDER AND INTERFACES IN ORDER TO AVOID WRITING ERRONEOUS PROGRAMS AND DUPLICATING EFFORT."



**INSTRUCTOR NOTES**

**THE use clause could have been added in the last example. Explain its effect.**

**POINT OUT CONTEXT CLAUSE.**

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# RESOLUTION

- WHEN A COMPILATION UNIT IS COMPILED INTO A PROGRAM LIBRARY, IT AUTOMATICALLY HAS ACCESS TO THE INFORMATION IN CERTAIN LIBRARY UNITS, E.G.,

- A PACKAGE BODY HAS ACCESS TO ITS SPECIFICATION

- A SUBUNIT HAS ACCESS TO THE UNIT NAMED IN THE separate PREFIX

- IF ACCESS TO OTHER LIBRARY UNITS IS NEEDED, THE COMPILATION UNIT MUST INCLUDE A CONTEXT CLAUSE SPECIFYING THE REQUIRED UNITS:

```
with Text_IO;      -- context clauses
with Vector_Services;
procedure Compute_Tracking_Data is
...
end Compute_Tracking_Data;
```



**INSTRUCTOR NOTES**

POINT OUT THAT THE ORDER OF COMPILATION IS DEFINED BY THE LRM.

# COMPILATION ORDER

- A COMPILATION UNIT MUST BE COMPILED AFTER ALL LIBRARY UNITS NAMED BY ITS CONTEXT  
CLAUSE
- A SUBPROGRAM OR PACKAGE BODY MUST BE COMPILED AFTER THE CORRESPONDING SUBPROGRAM  
OR PACKAGE SPECIFICATION
- A SUBUNIT MUST BE COMPILED AFTER ITS PARENT COMPILATION UNIT

AS A GENERAL RULE:

A GIVEN UNIT MUST BE COMPILED AFTER ANY UNITS CONTAINING INFORMATION UPON WHICH IT  
DEPENDS.

- IF UNIT A MUST BE COMPILED BEFORE UNIT B, THEN IF A IS RECOMPILED B MUST BE  
RECOMPILED (UNLESS A SMART COMPILER CAN DETERMINE THAT ANY CHANGES MADE TO A DO  
NOT AFFECT B).

## INSTRUCTOR NOTES

"NOTE THAT EXECUTABLE STATEMENTS MAY APPEAR INSIDE PACKAGE BODIES. THESE STATEMENTS ARE EXECUTED WHEN THE PACKAGE BODY IS ELABORATED. IN THE CASE OF A LIBRARY PACKAGE, THIS HAPPENS ONCE, BEFORE THE MAIN PROGRAM IS EXECUTED. IN THE CASE OF A PACKAGE DECLARED INSIDE A SUBPROGRAM OR BLOCK STATEMENT, THIS HAPPENS EACH TIME THE SUBPROGRAM OR BLOCK IS ENTERED AND ANOTHER INSTANCE OF THE PACKAGE COMES INTO EXISTENCE. THE INTENDED PURPOSE OF THESE STATEMENTS IS TO INITIALIZE THE VARIABLES IN THE PACKAGE BODY." THE EXECUTION OF THE PACKAGE'S STATEMENTS OCCUR PRIOR TO THE PROGRAM'S STATEMENTS.

# SEPARATE COMPILATION EXAMPLE -- LIBRARY UNITS

```
• SINGLE COMPILATION UNIT
  procedure Processor is
    Small : constant := 20;
    Total : Integer := 0;

    package Stock is
      Limit : constant := 1000;
      Table : array (1 .. Limit) of Integer := (1 .. Limit => 0);
      procedure Restart;
    end Stock;

    package body Stock is
      procedure Restart is
        begin -- Restart
          for N in Table'Range
            loop
              Table (N) := 0;
            end loop;
          end Restart;
        end Stock;

      procedure Update (X : Integer) is
        use Stock;
        begin -- Update
          ...
          Table (X) := Table (X) + Small;
          ...
        end Update;
      begin -- Processor
        ...
        Update (10);
        ...
        Stock.Restart; -- reinitializes Table
        ...
      end Processor;
```

## INSTRUCTOR NOTES

## QUESTION: DO PACKAGE SPECIFICATIONS NEED BODIES?

ANSWER: NO, UNLESS THE PACKAGE SPECIFICATION CONTAINS A DECLARATION (OF A SUBPROGRAM OR PACKAGE) THAT REQUIRES A BODY.

IF TWO PROJECTORS ARE AVAILABLE KEEP 10-44 UP ON DISPLAY.

# SEPARATE COMPILATION EXAMPLE

## -- LIBRARY UNITS (Continued)

### • THREE COMPILATION UNITS

```
package Stock is
  Limit : constant := 1000;
  Table : array (1 .. Limit) of Integer := (1 .. Limit => 0);
  procedure Restart;
end Stock;
```

```
-----
package body Stock is
  procedure Restart is
  begin -- Restart
    for N in Table'Range
    loop
      Table(N) := 0;
    end loop;
  end Restart;
end Stock;
```

```
-----
with Stock;
procedure Processor is
  Small : constant := 20;
  Total : Integer := 0;
```

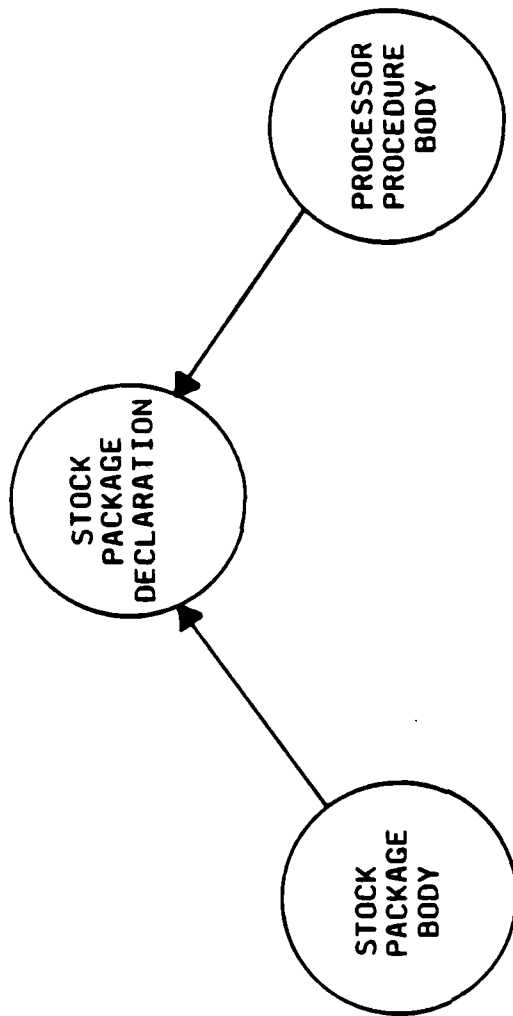
```

  procedure Update (X : Integer) is
  use Stock;
  begin -- Update
    ...
    Table (X) := Table (X) + Small;
    ...
  end Update;
begin -- Processor
  ...
  Update (10);
  ...
  Stock.Restart; -- reinitializes Table
  ...
end Processor;
```

**INSTRUCTOR NOTES**

IF 2 PROJECTORS ARE AVAILABLE, DISPLAY 10-45 CONCURRENTLY WITH THIS SLIDE.

# COMPILATION ORDER DEPENDENCIES



## POSSIBLE COMPILATION ORDERS:

- |    |                           |    |                           |
|----|---------------------------|----|---------------------------|
| 1. | STOCK PACKAGE DECLARATION | 1. | STOCK PACKAGE DECLARATION |
| 2. | STOCK PACKAGE BODY        | 2. | PROCESSOR PROCEDURE BODY  |
| 3. | PROCESSOR PROCEDURE BODY  | 3. | STOCK PACKAGE BODY        |



INSTRUCTOR NOTES

POINT OUT THAT THIS CODE RESIDES IN 1 TEXT FILE.

# SEPARATE COMPILATION EXAMPLE --- SUBUNITS

```
• SINGLE COMPILATION UNIT

with Text_IO;
procedure Top is
  type Real is digits 10;
  R, S : Real := 1.0;
  package Facility is
    pi : constant := 3.14159 26536;
    function F (X : Real) return Real;
    procedure G (Y, Z : Real);
  end Facility;
  package body Facility is
    -- some local declarations followed by
    function F (X : Real) return Real is
    begin -- F
      -- sequence of statements of F
      ...
    end F;
    procedure G (Y, Z : Real) is
    -- local procedures using Text_IO
    begin -- G
      -- sequence of statements of G
      ...
    end G;
  end Facility;
  procedure Transform (U : in out Real) is
  use Facility;
  begin -- Transform
    U := F(U);
    ...
  end Transform;
begin -- Top
  Transform (R);
  ...
  Facility.G (R, S);
end Top;
```

INSTRUCTOR NOTES

IF POSSIBLE DISPLAY 10-47 CONCURRENTLY.

POINT OUT USE OF THE SEPARATE CLAUSE.

# SEPARATE COMPILATION EXAMPLES

## - SUBUNITS (Continued)

- FOUR COMPILATION UNITS

```
procedure Top is
  type Real is digits 10;
  R, S : Real := 1.0;
  package Facility is
    pi : constant := 3.14159 26536;
    function F (X : Real) return Real;
    procedure G (Y, Z : Real);
  end Facility;
  package body Facility is separate;
  procedure Transform (U : in out Real) is separate;

  begin -- Top
    Transform (R);
    ...
    Facility.G (R, S);
  end Top;
```

---

```
separate (Top)
procedure Transform (U : in out Real) is
  use Facility;
  begin -- Transform
    U := F (U);
    ...
  end Transform;
```

---



# SEPARATE COMPILATION EXAMPLES

## FOUR COMPILATION UNITS (Continued)

```
separate (Top)
package body Facility is
    -- some local declarations followed by
    function F (X : Real) return Real is
    begin -- F
        -- sequence of statements of F
        ...
    end F;
    procedure G (Y, Z : Real) is separate;
end Facility;
```

3

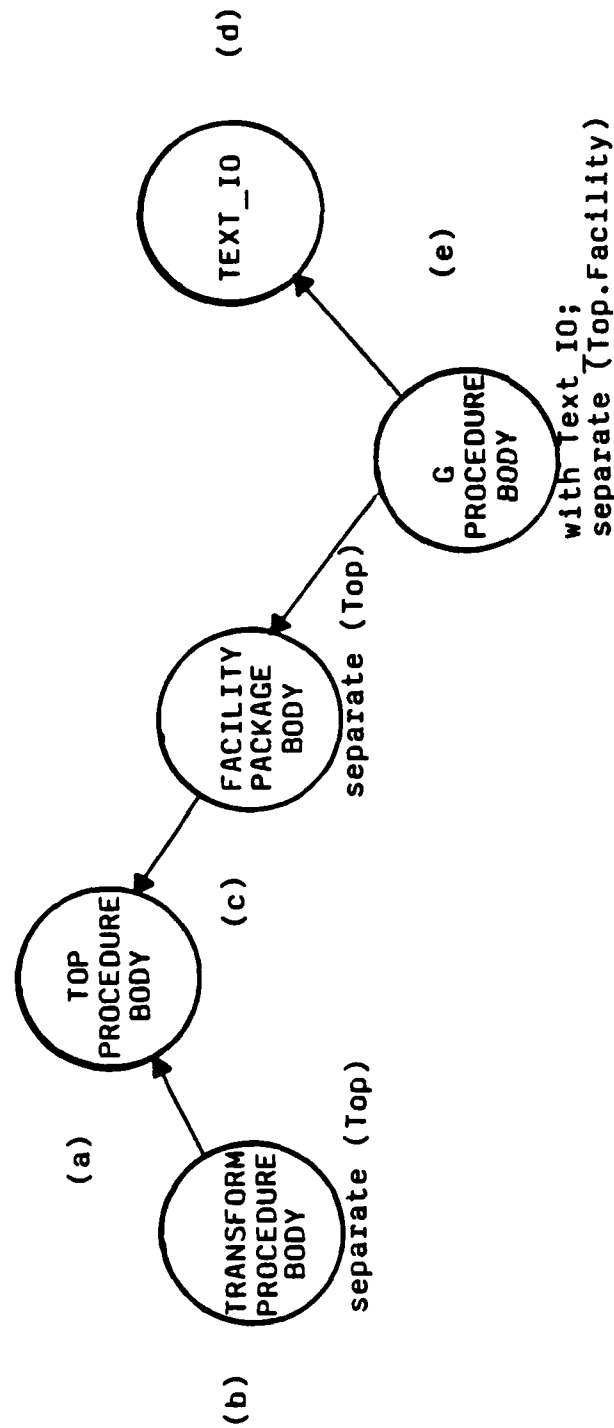
```
-----
with Text_IO;
separate (Top.Facility) -- full name of Facility
procedure G (Y, Z : Real) is
    -- local procedures using Text_IO
    ...
begin -- G
    -- sequence of statements of G
end G;
```

4

INSTRUCTOR NOTES

SPEND SOME TIME DISCUSSING THE VARIOUS POSSIBILITIES AND WHY THESE POSSIBILITIES ARE  
LEGAL.

# COMPILATION ORDER DEPENDENCIES



## POSSIBLE COMPILATION ORDERS:

(A)	(B)	(C)	(D)	(E)	*	(D)	(A)	(B)	(C)	(E)
(A)	(C)	(B)	(D)	(E)		(D)	(A)	(C)	(B)	(E)
(A)	(C)	(D)	(B)	(E)		(D)	(A)	(C)	(E)	(B)
(A)	(B)	(D)	(C)	(E)						
(A)	(D)	(B)	(C)	(E)						
(A)	(D)	(C)	(B)	(E)						
(A)	(C)	(D)	(E)	(B)						
(A)	(D)	(C)	(E)	(B)						

\*ACTUALLY, (d) -- Text\_IO -- IS "PRE-COMPILED," SO THESE POSSIBILITIES DO NOT ARISE.



## INSTRUCTOR NOTES

"AN EXAMPLE OF INFORMATION HIDING IS THE IMPLEMENTATION OF File\_Type IN Text\_IO. HOW THAT TYPE IS IMPLEMENTED DOES NOT CONCERN (OR INTEREST) THE USERS OF Text\_IO. IT IS HIDDEN FROM THEM."

ANOTHER EXAMPLE IS A LIST. OTHER PARTS OF THE PROGRAM MAY NEED TO MANIPULATE LISTS, SO YOU PROVIDE THEM WITH OPERATIONS, BUT NOT WITH THE INTERNAL REPRESENTATION. HELPS MAINTAIN CONSISTENCY.

ASSIGN EXERCISES 25 AND 26 AFTER FINISHING THIS SECTION.

ASSIGN CHAPTER 10 OF THE PRIMER.

# SEPARATE COMPILATION PRACTICE

- DECISIONS ON HOW AN Ada PROGRAM SHOULD BE BROKEN INTO SEPARATE COMPILATION UNITS SHOULD BEGIN WITH AN IDENTIFICATION OF LIBRARY PACKAGES.
- THE CRITERIA TO BE USED IN IDENTIFYING LIBRARY PACKAGES INCLUDE:
  - INFORMATION HIDING
  - ACCESS TO COMMON DATA
  - FUNCTIONAL COHESIVENESS
  - SOFTWARE DEVELOPMENT TEAM STRUCTURE

AD-A166 367

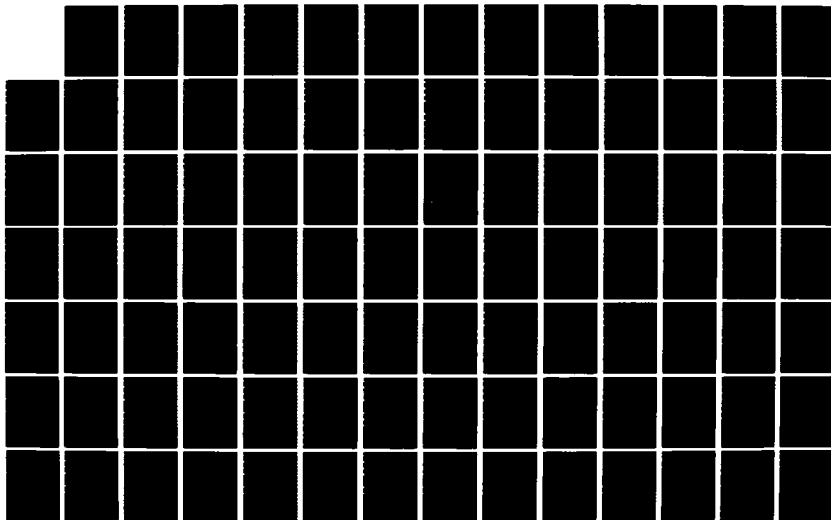
ADA (TRADE NAME) TRAINING CURRICULUM BASIC ADA  
PROGRAMMING L202 TEACHER'S GUIDE VOLUME 2(U) SOFTECH  
INC WALTHAM MA 1986 DAA007-83-C-K514

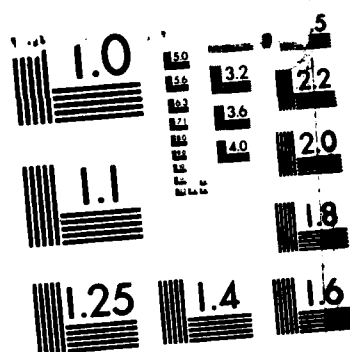
4/8

UNCLASSIFIED

F/G 9/2

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

## INSTRUCTOR NOTES

ALLOCATE 3 HOURS OF LECTURE TIME FOR THIS SECTION. AFTER PAGE 28 IS A GOOD BREAKING POINT FOR A 15 MINUTE COFFEE BREAK. ASSIGN EXERCISE 27 OF THE EXERCISE BOOKLET FOR LAB WORK. THE OBJECTIVE OF THIS SECTION IS TO INTRODUCE THE CONCEPT OF SCOPE AND VISIBILITY AND TO INTRODUCE THE STUDENT TO VARIOUS Ada CONSTRUCTS THAT HE/SHE MAY ENCOUNTER IN USING LIBRARY UNITS.

# **SECTION 12**

## **USING LIBRARY UNITS**

# INSTRUCTOR NOTES

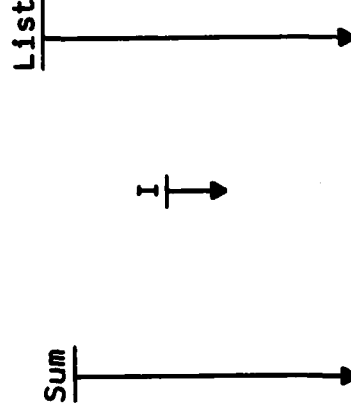
POINT OUT THAT WITHIN ALL THE PROGRAMS THEY WRITE, THE SCOPE OF ALL OBJECTS, TYPES ETC. THAT ARE DECLARED EXTENDS FROM THAT DECLARATION UNTIL THE END OF THE UNIT IT IS DECLARED IN. THEY ARE ABLE TO MANIPULATE OBJECTS, CALL PROCEDURES, ETC. BECAUSE THOSE IDENTIFIERS ARE IN SCOPE.

# SCOPE -- INTUITIVE IDEA

CONTEXT:    type Scores\_Type is digits 5 range 0.0 .. 100.0;  
              type List\_Type is array (1 .. 15) of Scores\_Type;

EXAMPLE:

```
function Mean (List : in List_Type) return Scores_Type is
  Sum : Scores := 0.0;
begin
  -- Mean
  for I in List'Range loop
    Sum := Sum + List (I);
  end loop;
  return Sum / Scores_Type (List'Last);
end Mean;
```



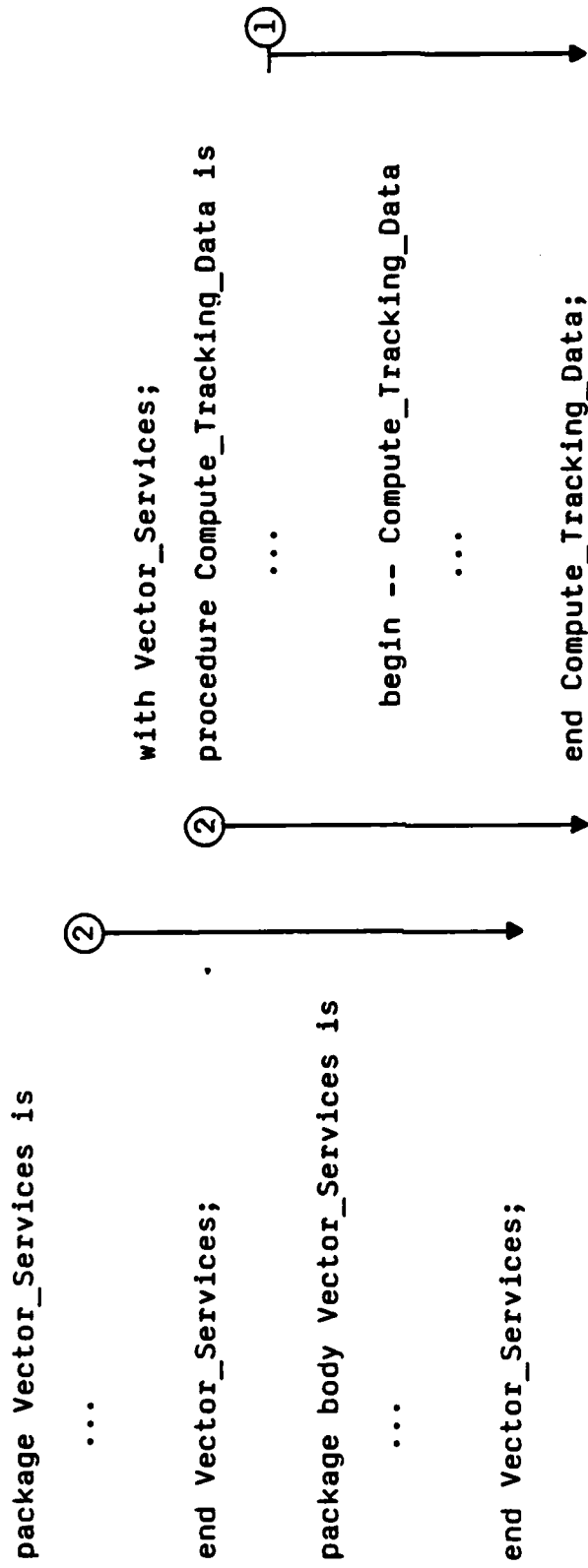
- SCOPE IS THE AREA IN WHICH AN IDENTIFIER IS KNOWN
- SCOPE EXTENDS FROM DECLARATION UNTIL END OF UNIT WITHIN WHICH IT IS DECLARED.



INSTRUCTOR NOTES

- ① ANYTHING DECLARED LOCAL TO THE PROCEDURE HAS SCOPE ONLY TO END OF PROCEDURE.
- ② ANYTHING DECLARED IN PACKAGE SPECIFICATION HAS SCOPE WHICH EXTENDS TO THE PACKAGE BODY AND TO ANY UNIT REFERENCING IT.
- ③ ANYTHING DECLARED IN PACKAGE BODY HAS SCOPE WHICH EXTENDS TO PACKAGE BODY ONLY.

## SCOPE -- INTUITIVE IDEA

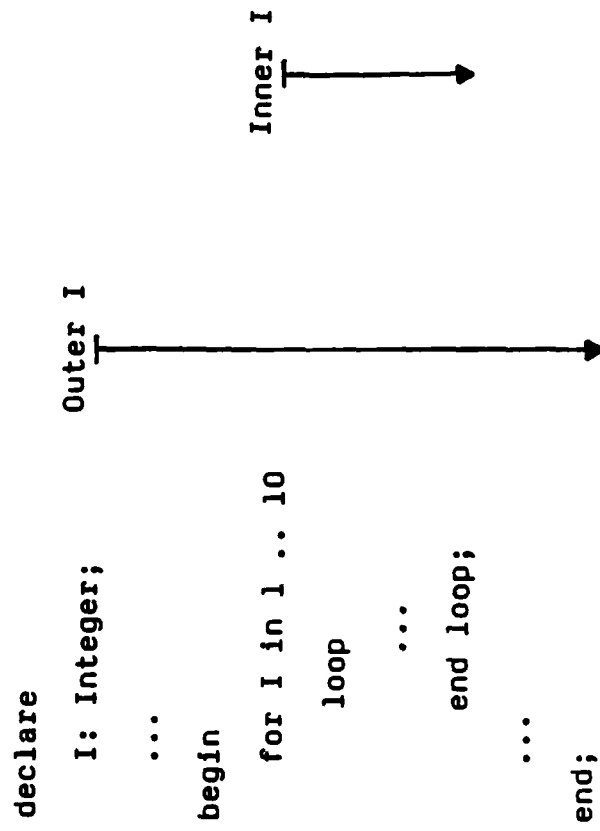


INSTRUCTOR NOTES

POINT OUT THAT THESE TWO I'S ARE DIFFERENT.

# SCOPE

- IT IS IMPORTANT TO UNDERSTAND SCOPE



INSTRUCTOR NOTES

POINT OUT THE DISTINCTION BETWEEN WHERE AN ENTITY IS KNOWN AND HOW IT IS REFERENCED.

## SCOPE -- DEFINITION

- RECALL THAT A DECLARATION ASSOCIATES AN IDENTIFIER WITH AN ENTITY SUCH AS A VARIABLE, A CONSTANT, A SUBPROGRAM, ETC.
- THE SCOPE OF A DECLARATION IS THE REGION OF PROGRAM TEXT POTENTIALLY INFLUENCED BY THAT DECLARATION.
- WITHIN THE SCOPE OF A DECLARATION AN OCCURRENCE OF THE DECLARED IDENTIFIER MAY BE RECOGNIZED AS A REFERENCE TO THE ENTITY ASSOCIATED BY THE DECLARATION.

INSTRUCTOR NOTES

THESE ARE 2 CONCEPTS RELATED TO SCOPE.

# RELATED CONCEPTS

- VISIBILITY

- DETERMINE WHERE WITHIN THE SCOPE THE IDENTIFIER WILL BE RECOGNIZED AS REFERRING TO THE ASSOCIATED ENTITY.

- LIFETIME

- THE DURATION OF PROGRAM EXECUTION DURING WHICH THE ENTITY EXISTS

THESE WILL BE ADDRESSED LATER IN THIS SECTION.



# INSTRUCTOR NOTES

THIS IS AN IMPORTANT FOIL. THE SCOPE RULES ARE COMPLEX SO IT IS IMPORTANT FOR THE STUDENT TO UNDERSTAND WHAT BENEFIT THE RULES HAVE.

## WHY WORRY ABOUT SCOPE ISSUES

- CONTROL WHAT IS GLOBAL AND WHAT IS NOT
- ALLOW EACH PROGRAMMER TO INVENT HIS OWN NAMES
- ALLOW EACH PROGRAMMER TO INVENT HIS OWN TEMPORARY DATA, BUFFERS, ETC.
- PREVENT A PROGRAMMER'S MODULES FROM INTERFERING WITH ANOTHER PROGRAMMER'S DATA/MODULES NOT INTENDED FOR SHARING

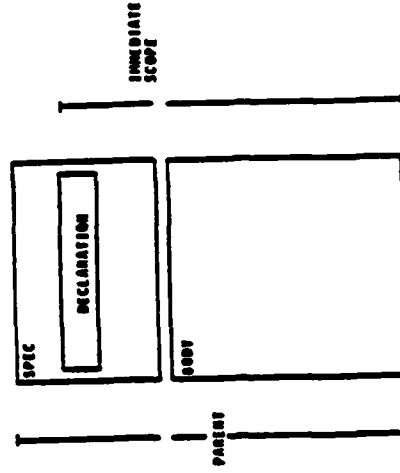
INSTRUCTOR NOTES

DECLARATIVE REGION IS ALMOST SYNONYMOUS WITH IMMEDIATE SCOPE. (IMMEDIATE SCOPE EXCLUDES THE PART OF THE DECLARATIVE REGION UP TO AND INCLUDING THE DECLARATION)

BLOCK STATEMENTS WILL BE DISCUSSED IN THE NEXT SECTION.

# IMMEDIATE SCOPE

- THE IMMEDIATE SCOPE OF A DECLARATION EXTENDS FROM THE DECLARATION TO THE END OF THE IMMEDIATELY ENCLOSING DECLARATIVE REGION. THIS IMMEDIATELY ENCLOSING REGION IS REFERRED TO AS THE PARENT OF THE DECLARATION.
- ENCLOSING DECLARATIVE REGIONS INCLUDE:
  - PACKAGE DECLARATIONS
  - SUBPROGRAM DECLARATIONS
 TOGETHER WITH CORRESPONDING BODIES, IF ANY
- RECORD TYPE DECLARATIONS
- BLOCK STATEMENTS
- LOOP STATEMENTS
- THE IMMEDIATE SCOPE INCLUDES BOTH THE SPECIFICATION AND BODY OF THE PARENT REGION AS IF THEY WERE ONE CONTIGUOUS TEXT REGION.



INSTRUCTOR NOTES

THE PARENT OF Point\_Type IS Vector\_Services SO THE IMMEDIATE SCOPE OF Point\_Type IS THE PACKAGE SPECIFICATION PLUS ITS BODY.

# SCOPE - PACKAGE DECLARATIONS

```

package Vector_Services is

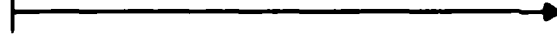
    type Coordinate_Type is (X,Y);
    type Point_Type is array (Coordinate_Type) of Float;
    subtype Time_Type is Duration;
    function Distance_Between (Last_Point, This_Point :
                               Point_Type) return Float;

end Vector_Services;

package body Vector_Services is
    ...
    function Distance_Between (Last_Point, This_Point :
                               Point_Type) return Float is
        Dx, Dy : Float;
    begin -- Distance_Between
        Dx := abs (This_Point(X) - Last_Point(X));
        Dy := abs (This_Point(Y) - Last_Point(Y));
        return ( Sqrt (Dx**2 + Dy**2) );
    end Distance_Between;
    ...
end Vector_Services;

```

Immediate Scope  
(Point\_Type)



INSTRUCTOR NOTES

SCOPE OF  $D_x$  &  $D_y$  IS THE ENCLOSING DECLARATIVE REGION - THE SUBPROGRAM Distance\_Between.





# INSTRUCTOR NOTES

A LOOP IS AN ENCLOSING DECLARATIVE REGION SO THE SCOPE OF I IS ONLY TO THE END OF THE LOOP.

# SCOPE - LOOP STATEMENT

## CONTEXT:


```
type Scores is digits 5 range 0.0 .. 100.0;
subtype Scores_Type is Scores range 0.0 .. 1500.0;
type List_Type is array (1 .. 15) of Scores_Type;
```

## EXAMPLE:

```
function Mean (List : List_Type) return Scores_Type is
    Sum : Scores := 0.0;
```

```
begin -- Mean
    for I in List'Range loop
        ...
    end loop;
    ...
end Mean;
```

Immediate Scope (I)



## INSTRUCTOR NOTES

### EXAMPLE - RECORD TYPE DECLARATIONS

```
type Rec is
record
    C1 : Boolean;
    C2 : Character;
    C3 : Integer;
end record;
```

↑                      ↓  
immediate scope

POINT OUT THAT IF THIS WERE THE ONLY SCOPE, RECORD COMPONENTS COULD NOT BE ACCESSED. BY EXTENDING THE SCOPE TO THE SCOPE OF THE PARENT, ACCESSING RECORD COMPONENTS IS ALLOWED.

STRESS POINT 4. ONLY THESE OBJECTS HAVE EXTENDED SCOPE. ONLY THESE OBJECTS ARE VISIBLE OUTSIDE THE PARENT UNIT.

# EXTENDED SCOPE

- HOWEVER SOME DECLARATIONS HAVE AN EXTENDED SCOPE THAT EXTENDS BEYOND THE PARENT.
- THE FULL SCOPE OF A DECLARATION IS THE IMMEDIATE SCOPE PLUS THE EXTENDED SCOPE (IF ANY).
- FOR MOST DECLARATIONS THE FULL SCOPE IS THE SAME AS THE IMMEDIATE SCOPE.
- DECLARATIONS WITH EXTENDED SCOPE INCLUDE:
  - DECLARATIONS IN THE VISIBLE PART OF A PACKAGE
  - SUBPROGRAM PARAMETERS (SO THEY CAN BE USED IN NAMED PARAMETER LISTS ANYWHERE THE SUBPROGRAM CAN BE CALLED)
  - RECORD COMPONENTS (SO THEY CAN BE ACCESSED ANYWHERE THE RECORD CAN BE)
- NOTE THAT DECLARATIONS WITH EXTENDED SCOPE ARE IN A SENSE PROPERTIES OF THE PARENT, SO IT IS REASONABLE THAT THEY HAVE AT LEAST THE SAME SCOPE AS THE PARENT.

INSTRUCTOR NOTES

POINT OUT THAT ITEMS DECLARED IN PACKAGE SPECIFICATIONS HAVE AN EXTENDED SCOPE.

# EXTENDED SCOPE - EXAMPLE

- ASSUME NO BODY FOR PACKAGE B.

package A is

...

package B is

Value\_1: Integer;

...

end B;

...

end A;

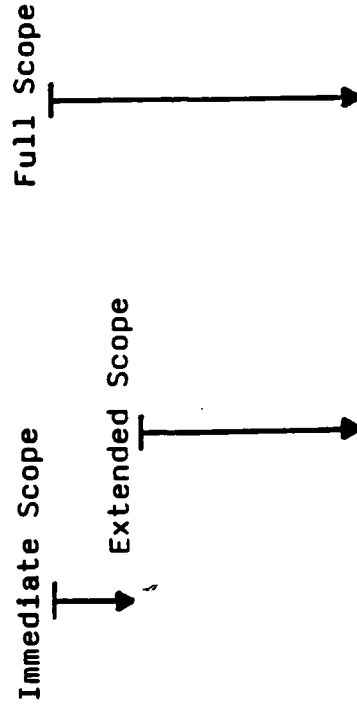
package body A is

...

end A;

- PARENT OF Value\_1 IS B

- SCOPE OF Value\_1 EXTENDS TO END OF SCOPE OF ENCLOSING DECLARATION (package A)



INSTRUCTOR NOTES



# EXTENDED SCOPE - EXAMPLE

- ASSUME B HAS A BODY

package A is

...

package B is

Value\_1 : Integer;

end B;

...

end A;

package body A is

package body B is

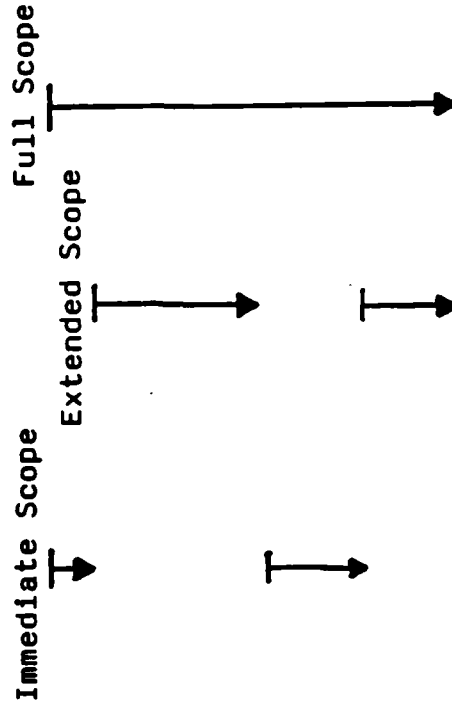
...

end B;

...

end A;

- B IS PARENT OF Value\_1





## INSTRUCTOR NOTES

POINT OUT THAT IT IS IMPORTANT TO UNDERSTAND SCOPE. IT EXPLAINS WHY THE I'S ARE DIFFERENT IN

declare

I : Integer;

begin

for I in 1 .. 10 loop

end loop;

end;

STRESS THAT ENTITIES IN PACKAGES HAVE EXTENDED SCOPE. ENTITIES IN PROCEDURES DO NOT.

# SCOPE -- WRAP UP

- ALTHOUGH THE SCOPE RULES ARE COMPLICATED TO STATE, THEIR IMPLICATIONS ARE STRAIGHTFORWARD:
  - NORMAL DECLARATIONS HAVE A SCOPE THAT INCLUDES ONLY THE CONTAINING REGION (THEY CANNOT BE ACCESSED OUTSIDE OF THAT UNIT)
  - DECLARATIONS VISIBLE OUTSIDE THE PARENT (VISIBLE PACKAGE DECLARATIONS, SUBPROGRAM PARAMETERS, RECORD COMPONENTS) HAVE A LARGER SCOPE

## INSTRUCTOR NOTES

"ENTITY EXISTS" - IT IS IN SCOPE

POINT OUT THAT THE ONLY WAY TO ACCESS A VALUE THAT IS NO LONGER IN SCOPE IS TO RE-ENTER ITS SCOPE. (IT WILL PROBABLY HAVE A NEW ADDRESS AND VALUE.)

"ELABORATE" ON THE LIFETIME OF LIBRARY PACKAGES. THEY ARE ELABORATED BEFORE THE MAIN PROGRAM BEGINS, AND REMAIN IN EXISTENCE UNTIL THE MAIN PROGRAM TERMINATES. SINCE THEY ARE, IN ESSENCE, PERMANENT, SO ARE THE ENTITIES DECLARED IN THEM.

THE TERMS USED IN BULLETS 3 AND 4 -- "ENTERING" AND "LEAVING" A SCOPE -- ARE IMPRECISE BUT MAY BE THE BEST WAY TO GET THE INTUITIVE IDEA ACROSS. IF STUDENTS ARE CONFUSED ABOUT "ENTERING" AND "LEAVING" THE SCOPE OF AN ITEM DECLARED IN A PACKAGE, GIVE THE GORY DETAILS:

1. LIBRARY UNITS ARE ELABORATED BEFORE THE MAIN PROGRAM IS EXECUTED. THE DECLARATIONS REMAIN IN EFFECT FOR THE DURATION OF THE MAIN PROGRAM.
2. DECLARATIONS OF BLOCK STATEMENTS OR SUBPROGRAM BODIES ARE ELABORATED BEFORE THE ACCOMPANYING STATEMENTS ARE EXECUTED AND REMAIN IN EFFECT UNTIL THE STATEMENTS HAVE TERMINATED.
3. A DECLARATION IN A PACKAGE SPECIFICATION (BODY) IS ELABORATED WHEN THE PACKAGE SPECIFICATION (BODY) IS ELABORATED. THE DECLARATION REMAINS IN EFFECT AS LONG AS THE DECLARATION OF THE PACKAGE. (IF THE PACKAGE IS A LIBRARY UNIT, USE RULE 1 ABOVE. IF DECLARED IN A SUBPROGRAM OR BLOCK STATEMENT, USE RULE 2 ABOVE. IF NESTED IN AN OUTER PACKAGE, APPLY RULE 3 RECURSIVELY TO THE OUTER PACKAGE.)
4. NEVER MIND TASKS JUST YET!

# LIFETIME

- THE LIFETIME OF AN ENTITY IS THE DURATION OF THE TOTAL PROGRAM EXECUTION DURING WHICH THE ENTITY EXISTS (I.E. IT IS IN SCOPE).
- THE LIFETIME OF AN ENTITY IS CONTROLLED BY THE SCOPE OF ITS DECLARATION.
- WHEN THE SCOPE IS ENTERED, THE DECLARATION WILL BE ELABORATED, CAUSING THE DECLARED ENTITY TO BE CREATED AND POSSIBLY INITIALIZED.
- WHEN THE SCOPE IS LEFT, THE ENTITY CEASES TO EXIST (FOR EXAMPLE, ITS STORAGE MAY BE RECLAIMED).
- THE RULES ENSURE THAT WHENEVER CONTROL IS WITHIN THE SCOPE OF AN ENTITY, THAT ENTITY WILL EXIST.
- AN ENTITY DECLARED IN A PACKAGE REMAINS IN EXISTENCE AS LONG AS THE PACKAGE. IN PARTICULAR, A VARIABLE DECLARED IN A PACKAGE BODY RETAINS ITS VALUE BETWEEN CALLS ON THE PACKAGE'S SUBPROGRAMS.
- GLOBAL ENTITIES WHOSE SCOPE IS ESSENTIALLY THE ENTIRE PROGRAM (FOR INSTANCE THOSE DECLARED IN THE MAIN PROGRAMS OR IN THE VISIBLE PART OF A LIBRARY PACKAGE) ARE ESSENTIALLY ALWAYS AROUND, SINCE THEY WILL BE CREATED AT THE BEGINNING OF THE PROGRAM EXECUTION AND WILL LAST UNTIL THE PROGRAM TERMINATES.
- ENTITIES DECLARED IN A SUBPROGRAM EXIST ONLY FOR A SINGLE CALL OF THAT SUBPROGRAM. (NEW ENTITIES WITH THE SAME NAME ARE CREATED THE NEXT TIME THE SUBPROGRAM IS CALLED.)

## INSTRUCTOR NOTES

"NOTE THAT EXECUTABLE STATEMENTS MAY APPEAR INSIDE PACKAGE BODIES. THESE STATEMENTS ARE EXECUTED WHEN THE PACKAGE BODY IS ELABORATED." IN THE CASE OF A LIBRARY PACKAGE, THIS HAPPENS ONCE, BEFORE THE MAIN PROGRAM IS EXECUTED. IN THE CASE OF A PACKAGE DECLARED INSIDE A SUBPROGRAM OR BLOCK STATEMENT, THIS HAPPENS EACH TIME THE SUBPROGRAM OR BLOCK IS ENTERED AND ANOTHER INSTANCE OF THE PACKAGE COMES INTO EXISTENCE. THE INTENDED PURPOSE OF THESE STATEMENTS IS TO INITIALIZE THE VARIABLES IN THE PACKAGE BODY. THE EXECUTION OF THE PACKAGE'S STATEMENTS OCCUR PRIOR TO THE PROGRAM'S STATEMENTS.

# SEPARATE COMPILATION EXAMPLE -- LIBRARY UNITS

```
• SINGLE COMPILATION UNIT
  procedure Processor is
    Small : constant := 20;
    Total : Integer := 0;

    package Stock is
      Limit : constant := 1000;
      Table : array (1.. Limit) of Integer;
      procedure Restart;
    end Stock;

    package body Stock is
      procedure Restart is
      begin -- Restart
        for N in Table'Range
        loop
          Table (N) := 0;
        end loop;
      end Restart;
    begin -- Stock
      Restart; -- Initialize the package
    end Stock;

    procedure Update (X : Integer) is
    use Stock;
    begin -- Update
      ...
      Table (X) := Table (X) + Small;
      ...
    end Update;

    begin -- Processor
      ...
      Update (10);
      ...
      Stock.Restart; -- reinitializes Table
      ...
    end Processor;
```

INSTRUCTOR NOTES

QUESTION: DO PACKAGE SPECIFICATIONS NEED BODIES?

ANSWER: NO, UNLESS THE PACKAGE SPECIFICATION CONTAINS A DECLARATION (OF A SUBPROGRAM OR PACKAGE) THAT REQUIRES A BODY.

# SEPARATE COMPILATION EXAMPLE

## -- LIBRARY UNITS (Continued)

### • THREE COMPILATION UNITS

```
package Stock is
  Limit : constant := 1000;
  Table : array (1 .. Limit) of Integer;
  procedure Restart;
end Stock;
-----
package body Stock is
  procedure Restart is
  begin -- Restart
    for N in Table'Range
      loop
        Table(N) := 0;
      end loop;
    end Restart;
  begin -- Stock
    Restart; -- Initialize the package
  end Stock;
-----
with Stock;
procedure Processor is
  Small : constant := 20;
  Total : Integer := 0;
  procedure Update (X : Integer) is
    use Stock;
  begin -- Update
    ...
    Table (X) := Table (X) + Small;
    ...
  end Update;
begin -- Processor
  ...
  Update (10);
  ...
  Stock.Restart; -- reinitializes Table
  ...
end Processor;
```



INSTRUCTOR NOTES

"VISIBILITY IS A SUBSET OF SCOPE. IF AN OBJECT IS VISIBLE THEN IT IS IN SCOPE. IF AN OBJECT IS IN SCOPE, IT MAY OR MAY NOT BE VISIBLE."

FOR EXAMPLE: RECORD COMPONENTS ARE IN SCOPE SO LONG AS THE RECORD IS IN SCOPE. RECORD COMPONENTS ARE DIRECTLY VISIBLE ONLY INSIDE THE RECORD TYPE DECLARATION.

# VISIBILITY -- DEFINITION

- THE REGION OF VISIBILITY OF A DECLARATION IS NORMALLY THE SAME AS THE SCOPE, THOUGH IN SOME CASES IT MAY BE SMALLER.
- THERE ARE TWO TYPES OF VISIBILITY:
  - DIRECT VISIBILITY IN WHICH THE DECLARED IDENTIFIER MAY BE USED ALONE TO REFER TO THE DECLARED ENTITY.
  - VISIBILITY BY SELECTION IN WHICH THE IDENTIFIER MUST BE PRECEDED BY A QUALIFYING PREFIX OR MUST APPEAR IN A CERTAIN CONTEXT TO BE RECOGNIZED AS AN OCCURRENCE OF THE DECLARED ENTITY.

INSTRUCTOR NOTES

AN EXAMPLE OF POINT 1:

procedure P is

A : Boolean;

A : Integer;

type B is

record

A : Integer;

end record;

function A return Boolean is separate; -- ILLEGAL

function C return Integer is

A : String (1 .. 10); -- LEGAL, NEW DECLARATIVE REGION

begin -- C

return 3;

end C;

begin -- P

null;

end P;

-- ILLEGAL BECAUSE IT IS IN THE SAME DECLARATIVE REGION

-- LEGAL BECAUSE RECORDS START A NEW DECLARATIVE REGION.

# DIRECT VISIBILITY

- A DECLARATION IS DIRECTLY VISIBLE ANYWHERE IN ITS IMMEDIATE SCOPE EXCEPT WHERE IT IS HIDDEN BY A DIFFERENT DECLARATION OF THE SAME IDENTIFIER IN AN ENCLOSED DECLARATIVE REGION.
- WHEN A DECLARATION IS DIRECTLY VISIBLE THE IDENTIFIER ALONE MAY BE USED TO REFER TO THE DECLARED ENTITY.
- FOR MOST DECLARATIONS DIRECT VISIBILITY IS THE NORMAL CASE.

```
procedure P is
    A : Boolean := True;
begin -- P
    A := not A; -- A IS DIRECTLY VISIBLE
end P;
```

INSTRUCTOR NOTES

# DIRECT VISIBILITY

USE OF A DECLARATION IN AN INNER REGION TO HIDE AN OUTER DECLARATION OF THE SAME IDENTIFIER IS CONFUSING TO THE READER AND SHOULD BE AVOIDED.

Visibility(Outer A)      procedure P is

                          A : Boolean := True;

                          begin -- P

                          declare

                          A : Boolean := False; -- inner A

                          begin

                          A := not A;

                          -- inner A

                          end;

                          A := not A;

                          -- outer A

                          end P;

OUTER A NOT DIRECTLY VISIBLE WITHIN INNER DECLARATIVE REGION.

## INSTRUCTOR NOTES

"A NAMED REGION COULD BE A LABELED BLOCK, LABELED LOOP, PACKAGE OR SUBPROGRAM."

### EXAMPLE OF NAMED NOTATION:

```
with Text_IO;  
procedure Hello_World is  
begin -- Hello_World  
    Text_IO.Put ("Hello");  
end Hello_World;
```

# VISIBILITY BY SELECTION

- A DECLARATION MAY BE MADE VISIBLE BY SELECTION BY PRECEDING THE DECLARED IDENTIFIER WITH A QUALIFYING PREFIX IDENTIFYING THE PARENT REGION CONTAINING THE DECLARATION.

## Prefix.Identifier

- THE QUALIFYING PREFIX PROVIDES A SMALL LOCAL WINDOW THROUGH WHICH A DECLARATION IN THE NAMED REGION MAY BE MADE VISIBLE.
- THE MOST USUAL QUALIFYING PREFIX IS JUST THE NAME OF A LIBRARY PACKAGE CONTAINING THE DESIRED DECLARATION.
- IN THE GENERAL CASE THE PREFIX MAY BE A LIST OF NAMES SEPARATED BY DOTS THAT IDENTIFIES A SUCCESSIVELY SMALLER SERIES OF REGIONS.



INSTRUCTOR NOTES

POINT OUT THAT THIS EXAMPLE IS TO ILLUSTRATE VISIBILITY BY SELECTION, IT IS NOT A MODEL  
FOR PROGRAMMING PRACTICE.

# VISIBILITY BY SELECTION

EXAMPLE:

```
procedure P is
  A : Boolean := True;
begin -- P
  declare
    A : Boolean := False; -- inner A
  begin
    P.A := A;
    end;
    A := not A;
  end P;
```

INSTRUCTOR NOTES

"THE WITH CLAUSE MAKES THE ENTITIES DECLARED IN THE VISIBLE PART OF THE LIBRARY UNIT  
VISIBLE BY SELECTION, I.E. YOU MUST QUALIFY THE NAME AS IN

Library\_Name.Entity

IF YOU JUST SAID Entity, THE COMPILER WOULD MARK IT AS AN UNDECLARED IDENTIFIER.

## with CLAUSES

- TO USE A SEPARATELY COMPILED PROGRAM UNIT IN ANOTHER SEPARATELY COMPILED PROGRAM UNIT, THE SECOND UNIT MUST CONTAIN A with CLAUSE SPECIFYING THE NAME OF THE PROGRAM UNIT BEING USED  

```
with Library_unit_name, ..., Library_unit_name;
```
- THE with CLAUSE MAKES THE DECLARATIONS IN THE VISIBLE PART OF THE NAMED PACKAGE VISIBLE BY SELECTION IN THE PROGRAM UNIT.
- THE with CLAUSE MUST APPEAR AT THE BEGINNING OF THE UNIT BEING COMPILED.
- WHY DO YOU NEED THE with CLAUSE? SO THAT READERS KNOW UP FRONT THE CONNECTIONS TO OTHER MODULES AND SO TYPOS CAN BE DETECTED (SIMILAR TO A DECLARATION, IN THIS RESPECT). SO THAT THE COMPILER KNOWS THAT YOU ARE REFERRING TO A PREVIOUSLY COMPILED LIBRARY UNIT, WHOSE DECLARATION WILL BE FOUND IN THE PROGRAM LIBRARY.

```
with Text_IO; -- Get and Put are resources provided by Text_IO
procedure Transfer is
  Line : String (1 .. 80);
begin -- Transfer
  Text_IO.Get (Line);
  Text_IO.Put (Line);
end Transfer;
```

## INSTRUCTOR NOTES

SOMEONE MAY ASK "IF A use CLAUSE ALWAYS REQUIRES A with CLAUSE, WHY DOESN'T THE use CLAUSE AUTOMATICALLY INCLUDE THE with?"

### ANSWER:

1. THE with CLAUSE MAKES THE NAME OF A LIBRARY UNIT DIRECTLY VISIBLE, AND THEREFORE ITS CONTENTS VISIBLE BY SELECTION.
2. THE use CLAUSE MAKES THE CONTENTS OF A PACKAGE DIRECTLY VISIBLE, PROVIDED THE NAME OF THE PACKAGE IS ALREADY VISIBLE.
3. WHEN PACKAGES ARE LIBRARY UNITS, BOTH CLAUSES ARE REQUIRED TO MAKE CONTENTS OF PACKAGE DIRECTLY VISIBLE.
4. HOWEVER, THE PACKAGE MAY ALREADY BE VISIBLE (FOR EXAMPLE IT MAY HAVE BEEN DECLARED WITHIN THIS PROGRAM UNIT). IN SUCH A CASE, THE use CLAUSE ALONE IS REQUIRED. IN FACT, A with CLAUSE ISN'T EVEN ALLOWED, SINCE IT WOULD MAKE THE COMPILER LOOK FOR A LIBRARY UNIT BY THAT NAME.

POINT OUT THAT SHOULD YOU HAVE A with Some\_Package, YOU COULD FOLLOW IT BY SOME DECLARATIONS, THEN APPLY THE use CLAUSE FOR THAT PACKAGE. UNTIL THE use, ANY DECLARATIONS WHICH USE Some\_Package MUST USE DOT NOTATION.

REMINDE THE CLASS THAT with CLAUSES ONLY GO AT THE TOP OF A COMPILATION UNIT. A USE CLAUSE MAY FOLLOW THE with CLAUSE OR APPEAR AS A DECLARATION.

## use CLAUSES

- A use CLAUSE MAY BE USED IN CONJUNCTION WITH A with CLAUSE TO MAKE DECLARATIONS IN SEPARATELY COMPILED PACKAGES DIRECTLY VISIBLE SO THEY CAN BE USED WITHOUT A QUALIFYING PREFIX

use Package\_Name, ... , Package\_Name;

- THE use CLAUSE MAY APPEAR IMMEDIATELY AFTER THE with CLAUSE OR IT MAY APPEAR ANYWHERE AN ORDINARY DECLARATION CAN APPEAR.
- A use CLAUSE AT THE TOP WITH THE with CLAUSE MAKES THE DECLARATIONS IN THE PACKAGE DIRECTLY VISIBLE THROUGH THE COMPILED UNIT.
- A use CLAUSE IN THE PLACE OF A DECLARATION MAKES THE DECLARATIONS DIRECTLY VISIBLE ONLY IN THE DECLARATIVE REGION CONTAINING THE use CLAUSE.
- DECLARATIONS MADE VISIBLE BY A use CLAUSE MAY BE HIDDEN BY A LOWER LEVEL DECLARATION OF THE SAME IDENTIFIER.

INSTRUCTOR NOTES

POINT OUT THAT IN THE BODY OF P, Q.B CANNOT BE ACCESSED. OBJECTS IN Q DON'T HAVE THE  
EXTENDED SCOPE NECESSARY TO DO THAT BECAUSE Q IS A PROCEDURE. OBJECTS IN PACKAGE HAVE  
EXTENDED SCOPE.

## VISIBILITY EXAMPLES

```
with Text_IO; use Text_IO;
procedure Transfer is
  Line : String (1 .. 80);
begin -- Transfer
  Get (Line);
  Put (Line);
end Transfer;
```

---

```
procedure P is
  A, B : Boolean;

  procedure Q is
    C : Boolean;
    B : Boolean; -- inner B
  begin -- Q
    ...
    B := A;      -- means Q.B := P.A;
    C := P.B;    -- means Q.C := P.B;
  end Q;
begin -- P
  ...
  A := B; -- means P.A := P.B;
end P;
```





# NAME CONFLICT

- RATIONALE: IF AN UNWANTED IDENTIFIER IS UNWITTINGLY IMPORTED (BECAUSE IT'S IN THE SAME PACKAGE AS A NEEDED ONE), IT WON'T CAUSE PROBLEMS, BECAUSE A DECLARATION WITHIN THE PROGRAM UNIT HIDES THE IMPORTED ONE.
- IF A PACKAGE DECLARATION P CONTAINS A DECLARATION OF AN ENTITY X, THEN WITHIN THE SCOPE OF ANOTHER ENTITY NAMED X, THE USE CLAUSE  
    use P;  
USUALLY DOES NOT APPLY TO X. THE X IN P MUST BE REFERRED TO AS P.X DESPITE THE USE CLAUSE.
- IF PACKAGE DECLARATIONS P AND Q BOTH CONTAIN ENTITIES NAMED X, THEN IF THE USE CLAUSES  
    use P;  
    use Q;  
OCCUR IN THE SAME DECLARATIVE REGION, NEITHER APPLIES TO THE CORRESPONDING X. THE ENTITIES MUST BE REFERRED TO AS P.X AND Q.X.
- EXCEPTION: IF THE TWO ENTITIES NAMED X CAN BE INTERPRETED AS OVERLOADED SUBPROGRAMS, THE USE CLAUSE IS APPLIED AND THE SUBPROGRAMS ARE OVERLOADED. (OVERLOADED SUBPROGRAMS ARE TWO SUBPROGRAMS THAT CO-EXIST WITH THE SAME NAME. THEY WILL BE DISCUSSED LATER.)



## HIDING EXAMPLE

```

package Numeric_Integration is
    type Integrand is array (0 .. 200) of Float;

    function Simpson (X      : Integrand;
                      Delta_t : Float)
        return Integrand;

    function Runge_Kutta (X      : Integrand;
                          Delta_t : Float)
        return Integrand;

end Numeric_Integration;
-- I want this
-- I don't want this
-- I want this

```

```

with Numeric_Integration; use Numeric_Integration;
procedure Dynamic_System_Simulation is

    Acceleration, Velocity, Displacement : Integrand;
    t, Dt, V0, D0 : Float;

    function Simpson (F : Integrand;
                      Dt : Float)
        return Integrand is
    ...
    end Simpson;
begin -- Dynamic_System_Simulation
    ...
    Velocity := Runge_Kutta (Acceleration, Dt);
    Displacement := Simpson (Velocity, Dt);
    ...
end Dynamic_System_Simulation;
-- My own declaration hides the
-- imported one

```

## INSTRUCTOR NOTES

"THE SOFTWARE ENGINEERING GOALS ARE READABILITY, PORTABILITY, AND MAINTAINABILITY."

use CLAUSES ARE APPROPRIATE WHEN THE ENTITIES PROVIDED BY THE PACKAGE ARE:

1. NAMES WITH GENERALLY RECOGNIZABLE MEANINGS (PUT, GET, SIN, COS, TAN)
2. OPERATOR SYMBOLS (BUT TRY NOT TO MENTION THIS SINCE THIS FEATURE HASN'T BEEN COVERED YET)

# COMMON PRACTICE

- RECALL THAT ONE OF THE MAIN SOFTWARE ENGINEERING GOALS SUPPORTED BY Ada IS TO PRODUCE READABLE PROGRAMS. IN THIS SPIRIT, WE SHOULD AVOID CONFUSING NESTS OF DECLARATIONS SOME OF WHICH HIDE OTHERS
- EXCEPT FOR DECLARATIONS IN LIBRARY PACKAGES, VIRTUALLY ALL DECLARATIONS WILL BE USED WHERE THEY ARE DIRECTLY VISIBLE
- HIDING SHOULD BE AVOIDED
- THE PRIMARY USE OF VISIBILITY BY SELECTION WILL BE TO ACCESS RECORD COMPONENTS AND TO ACCESS DECLARATIONS IN LIBRARY PACKAGES
- EXCEPT FOR NESTED RECORDS, QUALIFICATIONS WILL SELDOM EXTEND TO MORE THAN ONE PREFIX LEVEL
- EXCESSIVE USE OF use CLAUSES SHOULD BE AVOIDED SINCE THEY RESULT IN LARGE NUMBERS OF NAMES BECOMING DIRECTLY VISIBLE, CONFUSING THE READER OF THE PROGRAM

## INSTRUCTOR NOTES

A NEW SUBSECTION STARTS HERE. THE QUESTION DOES NOT REFER BACK TO THE MATERIAL COVERED SO FAR, BUT IS LEAD-IN QUESTION, "WHAT DO SOME OF THE OTHER THINGS WE ENCOUNTER IN PACKAGE SPECIFICATIONS MEAN?"

AS YOU SEE MORE AND MORE PACKAGE SPECIFICATIONS, YOU WILL ENCOUNTER VARIOUS Ada CONSTRUCTS. IN ORDER TO USE THE PACKAGE CORRECTLY, WE MUST LEARN WHAT THEY MEAN.

# WHAT DOES THAT MEAN ?

SOME ADDITIONAL CONSTRUCTS THAT YOU MAY ENCOUNTER IN PACKAGE SPECIFICATIONS.



## INSTRUCTOR NOTES

"FROM TIME TO TIME YOU WILL ENCOUNTER A PACKAGE CONTAINING A private OR limited private TYPE. THIS IS MAINLY TO PREVENT PROGRAMMERS FROM USING "SHORT CUTS" BASED ON KNOWLEDGE OF THE IMPLEMENTATION (IF THE IMPLEMENTATION IS CHANGED, THE SHORT CUTS WON'T WORK). YOU USE private TYPES AS YOU WOULD ANY OTHER OBJECTS, EXCEPT THAT YOU ARE RESTRICTED AS TO WHICH OPERATIONS ARE ALLOWED." FOR EXAMPLE:

```
package Text_IO is
...
type File_Type is limited private;
procedure Close (File : in File_Type);
...
private
type File_Type is <implementation-defined>;
end Text_IO;
with Text_IO; use Text_IO;
procedure Q is
F : File_Type;
begin -- Q
...
Close (F); -- LEGAL
F := Some_Value; -- ILLEGAL
end Q;
```

(WHEN A PRIVATE TYPE HAS DISCRIMINANTS, EXAMINATION OF THE DISCRIMINANTS IS ALLOWED, INCLUDING USING A MEMBERSHIP TEST TO DETERMINE THE SUBTYPE OF AN OBJECT.)

# PRIVATE TYPES: BASIC IDEA

- DECLARE A TYPE BUT CONCEPTUALLY HIDE THE IMPLEMENTATION FROM USER, I.E. PROGRAMMER CANNOT ACCESS THE IMPLEMENTATION
- DATA ABSTRACTION AND ENCAPSULATION
- CAN BE DECLARED ONLY WITHIN PACKAGE SPECIFICATION
- OPERATIONS ALWAYS AVAILABLE OUTSIDE PACKAGE ARE:
  - ASSIGNMENT
  - EQUALITY/INEQUALITY
  - OPERATIONS SPECIFIED IN VISIBLE PART
- limited private types PERMIT ONLY OPERATIONS SPECIFIED IN VISIBLE PART

## INSTRUCTOR NOTES

### EXAMPLES OF RENAMING STATEMENTS

```
procedure Write (S: in String) renames Text_IO.Put_Line;  
L : Language_Type renames Native_Language_In;
```

POINT OUT THAT YOU CAN RENAME COMPONENTS OF RECORDS.

# ADDITIONAL SCOPE AND VISIBILITY TOPICS

- Ada PROVIDES A FEW OTHER FEATURES THAT WILL NOT BE DISCUSSED HERE IN GREAT DETAIL

- RENAMING DECLARATIONS

SYNTAX:

Newdecl renames Oldname;

Newdecl: Type\_Name renames Oldname;

- ALLOWS ASSOCIATING A DIFFERENT IDENTIFIER WITH AN EXISTING ENTITY OVER SOME PART OF THE PROGRAM
- USED PRIMARILY TO AVOID NAME CONFLICTS IN SEPARATELY DEVELOPED PACKAGES OR TO PROVIDE A SHORTHAND NOTATION. A SEQUENCE OF RENAMING DECLARATIONS IS OFTEN BETTER (IN TERMS OF PROGRAM READABILITY) THAN A use CLAUSE.

INSTRUCTOR NOTES

RENAMING A VARIABLE.

## RENAMING EXAMPLE

```
procedure P is
  A : Boolean := True;
begin -- P
  declare
    Outer_A : Boolean renames P.A;
    A       : Boolean := False; -- inner A
  begin
    Outer_A := A;
  end;
  A := not A;
end P;
```



# OVERLOADING

- IT IS LEGAL FOR MORE THAN ONE DECLARATION OF A SPECIFIC IDENTIFIER TO BE VISIBLE IF REFERENCES TO THE DIFFERENT DECLARATIONS CAN BE DISTINGUISHED BY THE CONTEXT IN WHICH THEY OCCUR
  - THIS IS MOST FREQUENTLY SEEN IN THE CASE OF A FAMILY OF SUBPROGRAM DECLARATIONS WITH THE SAME NAME BUT WITH PARAMETERS OF DIFFERENT TYPES
- EXAMPLE:      Get AND Put



INSTRUCTOR NOTES

# SUBPROGRAM OVERLOADING

- TWO OR MORE SUBPROGRAMS MAY HAVE THE SAME NAME IF THEY HAVE DIFFERENT NUMBERS OR TYPES OF OPERANDS
- THE SUBPROGRAMS CAN THEN BE DISTINGUISHED BY THE PATTERN OF THEIR OPERANDS
- CONTEXT:  
    with Text\_IO; use Text\_IO;  
        -- defines Put and Get for Strings  
package Int\_IO is new Integer\_IO (Integer); use Int\_IO;  
    -- defines Put and Get for Integer

## EXAMPLES:

```
Put ("NAME:"); -- uses Text_IO.Put  
Put (3); -- uses Int_IO.Put
```

- EXCESSIVE USE OF SUBPROGRAM OVERLOADING IS HAZARDOUS TO THE HEALTH AND PATIENCE OF A PROGRAM READER OR MAINTAINER

INSTRUCTOR NOTES

POINT OUT THAT THIS ALLOWS THE PROGRAMMER TO CHOOSE NAMES WITHOUT FEAR OF CONFLICT.

# OVERLOADING - ENUMERATION LITERALS

SAME ENUMERATION LITERAL MAY BE USED IN MORE THAN ONE TYPE DECLARATION

```
type Counting_Format is (Binary, BCD);  
type Tape_Format is (ASCII, EBCDIC, Binary);  
type Interrupt_Status is (Yes, No);  
type Answer is (Yes, No, Maybe);
```

INSTRUCTOR NOTES

POINT OUT THAT WE ARE ALREADY USING OVERLOADED + WHEN WE ADD INTEGERS AND FLOATS SINCE THE LANGUAGE SUPPLIES A DIFFERENT FUNCTION FOR EACH TYPE.

# OPERATOR OVERLOADING

IT IS POSSIBLE TO EXTEND OPERATORS TO OTHER DATA TYPES BY USE OF OVERLOADING

EXAMPLE:

OPERATORS (+, -, \*, /, \*\*, >, <, >=, <=, =, /=) ARE CONSIDERED TO BE FUNCTIONS IN Ada, FOR THE USER'S NOTATIONAL CONVENIENCE, INFIX NOTATION IS ALLOWED:

a < b RATHER THAN "<(a,b)

SUPPOSE YOU HAVE A PROGRAM THAT HAS A RECORD TYPE Date TO HOLD THE DATE. FOR INSTANCE, AN OBJECT Today OF TYPE Date MIGHT BE ASSIGNED

Today := (March, 4, 1983);

IT WOULD BE NICE, GIVEN TWO Date OBJECTS, TO BE ABLE TO COMPARE THEM:

```
if Due_Date < Today
then
    Put ( " O V E R D U E : " );
end if;
```

## INSTRUCTOR NOTES

POINT OUT THAT ONLY PREDEFINED OPERATORS CAN APPEAR INSIDE THE " " FOR OVERLOADING.

PREDEFINED "=" IS NOT AVAILABLE FOR limited TYPES.

IF THE CLASS IS CLAMORING FOR A DEFINITION OF limited TYPES, SAY THEY INCLUDE:

1. TYPES DECLARED AS limited private. (FOR FURTHER DETAILS, TAKE L305)
2. SPECIFIC TYPES KNOWN AS "TASK TYPES." (FOR FURTHER DETAILS, TAKE L401)
3. A RECORD TYPE OR ARRAY TYPE WITH A limited COMPONENT.

## OPERATOR OVERLOADING (Continued)

NORMALLY, Ada DOES NOT ALLOW YOU TO COMPARE TWO RECORDS, ONLY THEIR COMPONENTS. HOWEVER, Ada DOES ALLOW YOU TO CREATE A NEW MEANING FOR THE "<" FUNCTION:

```
function "<" (Date_1, Date_2: Date) return Boolean is
begin
    -- "<"
    . . .
end "<";
```

NOW WE CAN WRITE:

```
if Due_Date < Today then ...
```

NOTE: THE ASSIGNMENT OPERATOR (":=") MAY NOT BE OVERLOADED.

THE EQUALITY OPERATOR ("=") MAY ONLY BE OVERLOADED FOR limited TYPES.

THE INEQUALITY OPERATOR ("<") MAY NOT BE EXPLICITLY OVERLOADED, BUT IT IS IMPLICITLY OVERLOADED WHEN YOU OVERLOAD "="



INSTRUCTOR NOTES

POINT OUT THAT THE ' ("TICK") IS NEEDED. THIS IS DIFFERENT FROM TYPE CONVERSION.

# OVERLOADING: TYPE AMBIGUITY AND QUALIFICATION

USUALLY THE COMPILER CAN SORT THINGS OUT. WHEN IN TROUBLE, Ada GIVES YOU A WAY OF UNIQUELY IDENTIFYING THE OVERLOADED LITERALS BY MEANS OF TYPE QUALIFICATION

Example:

Counting\_Format'(Binary)

Tape\_Format'(Binary)

IDENTIFYING NOTATION PRECEDES THE OVERLOADED LITERAL WITH ITS TYPE NAME AND AN APOSTROPHE.



# GENERIC PROGRAM UNITS - BASIC IDEA

- PROVIDE EFFECTIVE REUSE OF COMMON CODE
- ARE PARAMETERIZED TEMPLATES OF A PROGRAM UNIT
- WRITE CODE TO BE REUSED
- ENHANCE READABILITY
- BUILD LIBRARIES
- PARAMETERS ARE OBJECTS, TYPES, SUBPROGRAMS

INSTANTIATION PROVIDES THE PHYSICAL CODE FOR MANY SIMILAR BUT DIFFERENT TYPES

# INSTRUCTOR NOTES

"INSTANTIATION IS THE PROCESS OF TAILORING THE GENERAL PATTERN TO FIT A SPECIFIC INSTANCE. YOU CAN'T USE A GENERIC PACKAGE LIKE SWAP FOR ANYTHING EXCEPT INSTANTIATION."

"THE INSTANTIATION HAS THE SAME EFFECT AS WRITING A COPY OF Exchange AT THAT POINT, WITH ALL OCCURRENCES OF 'Exchange' REPLACED BY 'Swap' AND ALL OCCURRENCES OF 'Swap\_Type' REPLACED BY THE TYPE GIVEN IN THE INSTANTIATION."

"(SO THAT'S WHAT THOSE INCANTATIONS WERE!)"

# GENERIC UNITS

## EXAMPLE

### TEMPLATE:

```
generic -- GENERIC CLAUSE
    type Swap_Type is private;
    procedure Exchange (X, Y: in out Swap_Type);

    procedure Exchange (X, Y: in out Swap_Type) is
        Temp : Swap_Type := X;
    begin -- Exchange
        X := Y;
        Y := Temp;
    end Exchange;
```

### INSTANTIATIONS:

```
    procedure Swap is new Exchange (Integer);

    procedure Swap is new Exchange (Character);

    procedure Swap is new Exchange (Day);

    subtype Ten_Char_String is String (1 .. 10);
    procedure Swap is new Exchange (Ten_Char_String);
```



# A GENERIC PACKAGE

## Enumeration IO

### (part of Text IO)

```
generic
    type Enum is (<>);

package Enumeration_IO is
    subtype Field is Integer range 0 .. <implementation-defined>;
    type Type_Set is (Lower_Case, Upper_Case);
    Default_Width : Field := 0;
    Default_Setting : Type_Set := Upper_Case;
    procedure Get (File : in File_Type; Item : out Enum);
    procedure Put (File : in File_Type; Item : in Enum;
        Width : in Field := Default_Width;
        Set : in Type_Set := Default_Setting);
    .
    .
    .
end Enumeration_IO;

package body Enumeration_IO is
    -- implementation-dependent
end Enumeration_IO;
```



## INSTRUCTOR NOTES

AN EXAMPLE OF A GENERIC PARAMETER THAT IS A SUBPROGRAM.

```
generic
  type LP is limited private;
  with function Greater_Than (X, Y : LP) return Boolean;
package Pack is
  .
  .
  .
end Pack;
.
.
.
package New_Pack is new Pack (Integer, ">");
```

ASSIGN EXERCISE 27 OF THE EXERCISE BOOKLET.

ASSIGN CHAPTER 11 OF THE PRIMER.

# TYPE PARAMETERS FOR GENERICS

type T is private; -- only assignment and equality defined for T; any type  
-- actual except limited private

type T is limited private; -- no assignment, equality; any type actual

type T is (<>); -- discrete type

type T is range<>; -- integer type

type T is digits<>; -- floating point

type T is delta<>; -- fixed point

GENERIC PARAMETERS CAN ALSO BE SUBPROGRAMS

INSTRUCTOR NOTES

# **SECTION 13**

## **PACKAGES**

VG 728.2

## INSTRUCTOR NOTES

BULLET 1: EMBEDDED SYSTEMS ARE TYPICALLY HUNDREDS OF THOUSANDS OF LINES LONG. SUCH LARGE PROGRAMS CANNOT BE UNDERSTOOD ALL AT ONCE.

BULLET 2: EMBEDDED SYSTEMS ARE TYPICALLY DEVELOPED BY LARGE TEAMS OF TENS OR EVEN A FEW HUNDRED PEOPLE. IF EACH HAD TO BE AWARE OF THE OTHERS' WORK, CHAOS WOULD RESULT.

BULLET 3: CERTAIN ALGORITHMS AND DATA STRUCTURES ARE USED IN MANY DIFFERENT EMBEDDED SYSTEMS. SOFTWARE COSTS CAN BE REDUCED BY PLUGGING "OFF-THE-SHELF COMPONENTS" INTO NEW SYSTEMS INSTEAD OF BUILDING THE COMPONENTS FROM SCRATCH EACH TIME.

IN Ada, THESE CONSIDERATIONS ARE ADDRESSED BY PACKAGES.

# PACKAGES

- SOME GOALS OF Ada:
  - BE ABLE TO WRITE HUGE PROGRAMS WHICH CAN BE UNDERSTOOD  
PIECE-BY-PIECE.
  - BE ABLE TO DIVIDE A PROGRAMMING PROJECT AMONG TEAMS  
WORKING INDEPENDENTLY.
  - BE ABLE TO WRITE GENERAL SOFTWARE COMPONENTS THAT CAN  
BE INCORPORATED IN MANY PROGRAMS
- THESE ABILITIES ARE PROVIDED BY PACKAGES

## INSTRUCTOR NOTES

UNLIKE A SUBPROGRAM, A PACKAGE DOES NOT EXIST IN ORDER TO BE EXECUTED.

A PACKAGE PROVIDES A COLLECTION OF COMPUTATIONAL RESOURCES THAT MAY BE USED BY ONE OR MORE OTHER PROGRAM COMPONENTS.

THESE RESOURCES INCLUDE VARIABLES, TYPE DECLARATIONS, PROCEDURES, AND FUNCTIONS, AMONG OTHERS.

RESOURCES SHOULD BE PLACED IN THE SAME PACKAGE IF THEY ARE CLOSELY RELATED, AND MEANT TO BE USED IN CONJUNCTION WITH EACH OTHER.



# WHAT IS A PACKAGE?

A PACKAGE IS A COLLECTION OF RELATED ENTITIES INCLUDING  
(AMONG OTHERS):

- VARIABLES
- TYPE DECLARATIONS
- PROCEDURES
- FUNCTIONS

PACKAGES ARE THE BASIC BUILDING BLOCKS OF LARGE PROGRAMS.

OTHER NAMES FOR PACKAGES:

MODULES, CLUSTERS, PROGRAM COMPONENTS



# INSTRUCTOR NOTES

THIS IS A DESCRIPTION OF AN Ada PACKAGE PROVIDING TWO NAMED NUMBERS, THREE SUBTYPES OF TYPE FLOAT, AND 16 FUNCTIONS. THE PACKAGE CONSISTS OF THIS DESCRIPTION PLUS A BODY CONTAINING THE BODIES OF THE 16 FUNCTIONS.

# EXAMPLE: A PACKAGE PROVIDING MATHEMATICAL FUNCTIONS AND VALUES

```
package Math_Package is

  Pi : constant := 3.14159265358979;
  e  : constant := 2.71828182845904;

  subtype Non_Negative_Float is Float range 0.0 .. Float'Last;
  subtype Trigonometric_Subtype is Float range -1.0 .. 1.0;
  subtype Principal_Angle_Subtype is Float range -Pi/2 .. Pi/2;

  function Square_Root
    (Square: Non_Negative_Float) return Non_Negative_Float;
  function Sine (Radians: Float) return Trigonometric_Subtype;
  function Cosine (Radians: Float) return Trigonometric_Subtype;
  function Tangent (Radians: Float) return Float;
  function Cotangent (Radians: Float) return Float;
  function Secant (Radians: Float) return Float;
  function Cosecant (Radians: Float) return Float;
  function Arc_Sine
    (Sine: Trigonometric_Subtype) return Principal_Angle_Subtype;
  function Arc_Cosine
    (Cosine: Trigonometric_Subtype) return Principal_Angle_Subtype;
  function Arc_Tangent (Tangent: Float) return Principal_Angle_Subtype;
  function Arc_Cotangent (Cotangent: Float) return Principal_Angle_Subtype;
  function Arc_Secant (Secant: Float) return Principal_Angle_Subtype;
  function Arc_Cosecant (Cosecant: Float) return Principal_Angle_Subtype;
  function Exponential (Exponent: Float) return Non_Negative_Float;
  function Natural_Logarithm (Power: Non_Negative_Float) return Float;
  function Common_Logarithm (Power: Non_Negative_Float) return Float;

end Math_Package;
```

## INSTRUCTOR NOTES

IN Ada, A SHARP DISTINCTION IS DRAWN BETWEEN THE INTERFACE OF A PACKAGE AND ITS IMPLEMENTATION.

THE INTERFACE EXPLAINS HOW THE ENTITIES PROVIDED BY THE PACKAGE TO THE OUTSIDE WORLD ARE TO BE USED.

THE IMPLEMENTATION EXPLAINS HOW THESE ENTITIES WORK INTERNALLY.

AN ANALOGY CAN BE DRAWN TO A STEREO RECEIVER: THE FRONT PANEL IS THE INTERFACE AND THE ELECTRONIC COMPONENTS INSIDE THE RECEIVER ARE THE IMPLEMENTATION.

# INTERFACE VERSUS IMPLEMENTATION

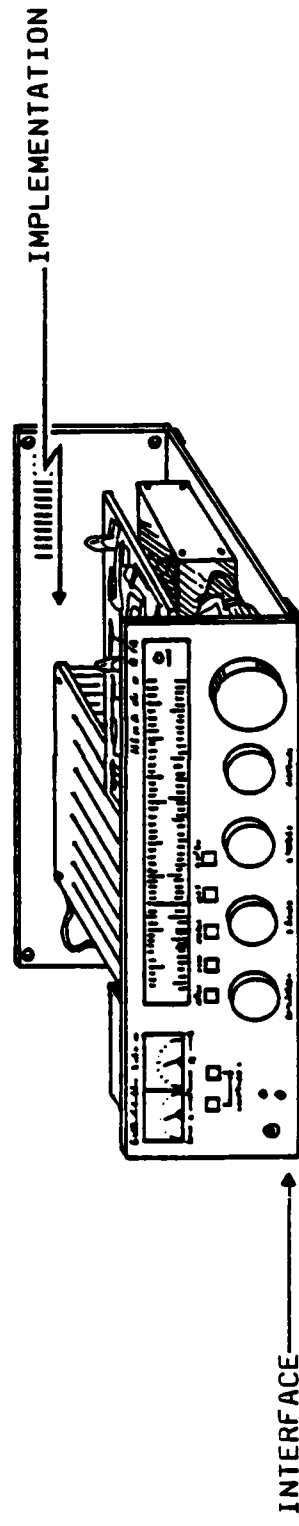
INTERFACE:

EXTERNAL APPEARANCE OF A PACKAGE

IMPLEMENTATION:

INTERNAL WORKINGS OF A PACKAGE

ONLY THE INTERFACE IS RELEVANT TO THE USER OF A PACKAGE



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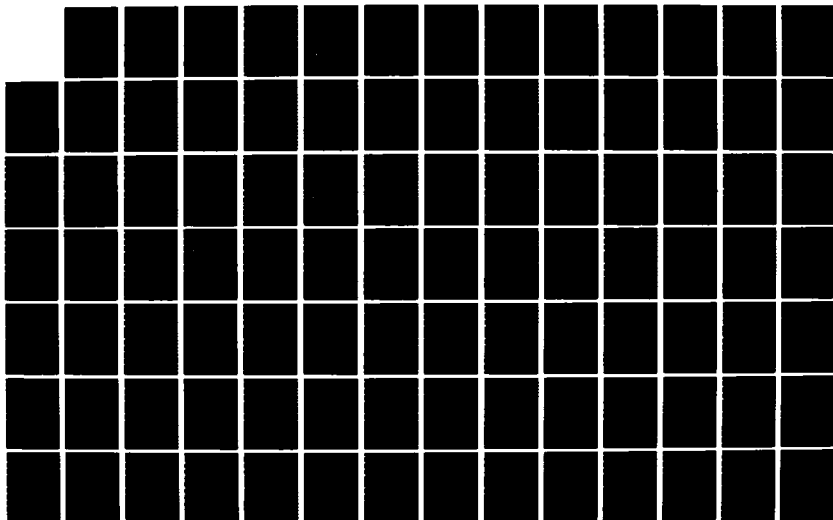
ADA (TRADE NAME) TRAINING CURRICULUM BASIC ADA  
PROGRAMMING L202 TEACHER'S GUIDE VOLUME 2(U) SOFTECH  
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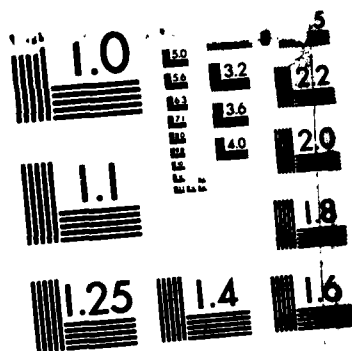
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## INSTRUCTOR NOTES

THE INTERFACE OF A PACKAGE INCLUDES SEVERAL KINDS OF INFORMATION DEFINED INSIDE THE PACKAGE FOR USE OUTSIDE THE PACKAGE.

BULLET 1: A PACKAGE MAY PROVIDE VARIABLES THAT CAN BE SET OR EXAMINED BY ALL USERS OF THE PACKAGE.

BULLET 2: A PACKAGE MAY DEFINE NEW TYPES OR SUBTYPES. PROGRAM UNITS USING THE PACKAGE MAY REFER TO THESE TYPES OR SUBTYPES IN VARIABLE AND SUBPROGRAM DECLARATIONS, FOR EXAMPLE.

BULLET 3&4: IF A PACKAGE PROVIDES A SUBPROGRAM TO THE OUTSIDE WORLD, THEN THE PACKAGE INTERFACE MUST INCLUDE INFORMATION ON HOW TO CALL THE SUBPROGRAM. PARAMETER NAMES ARE RELEVANT BECAUSE THEY MAY APPEAR IN NAMED SUBPROGRAM CALLS.

THE PACKAGE INTERFACE MAY INCLUDE INFORMATION BESIDE THAT DESCRIBED HERE.

# THE INTERFACE OF A PACKAGE

THE PACKAGE INTERFACE INCLUDES (AMONG OTHER THINGS):

- DECLARATIONS OF VARIABLES AVAILABLE TO ALL USERS OF THE PACKAGE
- TYPES DEFINED IN THE PACKAGE FOR USE OUTSIDE OF THE PACKAGE
- PROCEDURE NAMES, PARAMETER NAMES, AND PARAMETER TYPES FOR PROCEDURES DEFINED IN THE PACKAGE FOR USE OUTSIDE THE PACKAGE
- FUNCTION NAMES, PARAMETER NAMES, PARAMETER TYPES, AND RESULT TYPES FOR FUNCTIONS DEFINED IN THE PACKAGE FOR USE OUTSIDE THE PACKAGE



## INSTRUCTOR NOTES

THE IMPLEMENTATION OF A PACKAGE DESCRIBES THE INTERNAL MECHANISMS USED TO PROVIDE THE RESOURCES DESCRIBED IN THE PACKAGE INTERFACE.

THESE MECHANISMS ARE NOT DIRECTLY AVAILABLE OUTSIDE THE PACKAGE.

THE PROGRAMMING PRINCIPLE CALLED SEPARATION OF CONCERNS HOLDS THAT A PROGRAM USING A PACKAGE CAN BE STUDIED INDEPENDENTLY FROM TWO DIFFERENT VIEWPOINTS. ONE CAN STUDY THE RELATIONSHIP BETWEEN THE PACKAGE IMPLEMENTATION AND THE INTERFACE, OR THE RELATIONSHIP BETWEEN THE INTERFACE AND THE OTHER PARTS OF THE PROGRAM THAT USE THE PACKAGE; BUT IT IS NEVER NECESSARY TO CONSIDER THE IMPLEMENTATION AND THE USE OF THE PACKAGE AT THE SAME TIME. THIS MAKES IT POSSIBLE TO UNDERSTAND, DEVELOP, AND MODIFY A HUGE PROGRAM A PIECE AT A TIME.

# THE IMPLEMENTATION OF A PACKAGE

THE PACKAGE IMPLEMENTATION INCLUDES (AMONG OTHER THINGS):

- THE ALGORITHMS FOR ALL PROCEDURES AND FUNCTIONS DESCRIBED IN THE INTERFACE
- SUBPROGRAMS USED INTERNALLY BY THOSE PROCEDURES AND FUNCTIONS, BUT NOT CALLED DIRECTLY FROM OUTSIDE THE PACKAGE
- TYPES AND VARIABLES USED INTERNALLY TO IMPLEMENT THE PROCEDURES AND FUNCTIONS DESCRIBED IN THE INTERFACE

## INSTRUCTOR NOTES

THIS SLIDE RELATES THE LANGUAGE-INDEPENDENT NOTIONS OF INTERFACE AND IMPLEMENTATION TO Ada SYNTACTIC ENTITIES -- THE PACKAGE SPECIFICATION AND PACKAGE BODY.

A PACKAGE SPECIFICATION IS ESSENTIALLY A LIST OF DECLARATIONS OF ENTITIES TO BE USED OUTSIDE THE PACKAGE.

A PACKAGE BODY HAS THE SAME FORM AS A SUBPROGRAM BODY, EXCEPT FOR THE FIRST LINE. THE DECLARATIONS ARE OF ENTITIES CONSTITUTING THE IMPLEMENTATION OF THE PACKAGE. THESE MAY INCLUDE SUBPROGRAMS. THE INITIALIZATION STATEMENTS ARE EXECUTED ONCE, WHEN THE PACKAGE COMES INTO EXISTENCE.

THE WORD BEGIN AND THE STATEMENTS FOLLOWING IT MAY BE OMITTED (THE COMMENT FOLLOWING BEGIN IS OPTIONAL).

THE TERM PACKAGE GENERALLY REFERS COLLECTIVELY TO THE PACKAGE SPECIFICATION AND PACKAGE BODY.

# THE FORM OF A PACKAGE

A PACKAGE HAS TWO PARTS:

- PACKAGE SPECIFICATION -- DESCRIBES THE INTERFACE  
package [package name] is  
[sequence of declarations]  
end [package name];
- PACKAGE BODY -- DESCRIBES THE IMPLEMENTATION  
package body [package name] is  
[sequence of declarations]  
[begin -- [package name]  
[sequence of initialization statements]]  
end [package name];

## INSTRUCTOR NOTES

THIS IS THE SPECIFICATION OF A PACKAGE NAMED Earliest\_and\_Latest. IT PROVIDES TYPES NAMED Month\_Type, Day\_Type, and Date\_Type, TWELVE ENUMERATION LITERALS FOR Month\_Type VALUES, AND THREE SUBPROGRAMS.

THE FUNCTION Earliest\_Date\_Noted IS TO RETURN THE EARLIEST DATE WHICH HAS BEEN PASSED IN A PREVIOUS CALL TO Note\_Date, OR DECEMBER 31 IF Note\_Date HAS NOT YET BEEN CALLED. THE FUNCTION Latest\_Date\_Noted IS TO RETURN THE LATEST DATE WHICH HAS BEEN PASSED IN A PREVIOUS CALL TO Note\_Date, OR JANUARY 1 IF Note\_Date HAS NOT YET BEEN CALLED.

WITHIN THE PACKAGE SPECIFICATION THE SUBPROGRAMS PROVIDED BY THE PACKAGE ARE DESCRIBED BY SUBPROGRAM SPECIFICATIONS. SUBPROGRAM SPECIFICATIONS ARE IDENTICAL TO THE PART OF A SUBPROGRAM BODY PRECEDING THE WORD is. THEY INDICATE THE KIND OF SUBPROGRAM (PROCEDURE OR FUNCTION), THE NAME OF THE SUBPROGRAM, THE NAMES, MODES, AND SUBTYPES OF PARAMETERS, AND, IN THE CASE OF FUNCTIONS, THE RESULT SUBTYPE.

FOR EACH SUBPROGRAM SPECIFICATION APPEARING IN THE PACKAGE SPECIFICATION, A FULL SUBPROGRAM BODY MUST APPEAR IN THE PACKAGE BODY.

[IF A SECOND PROJECTOR IS AVAILABLE, KEEP THIS SLIDE ON THE SCREEN WHILE SHOWING THE NEXT TWO SLIDES.]

# EXAMPLE OF A PACKAGE SPECIFICATION

```
package Earliest_And_Latest is

  type Month_Type is
    (January, February, March, April, May, June, July,
     August, September, October, November, December);

  type Day_Type is range 1 .. 31;

  type Date_Type is
    record
      Month_Part : Month_Type;
      Day_Part   : Day_Type;
    end record;

  procedure Note_Date (Date : in Date_Type);

  function Earliest_Date_Noted return Date_Type;

  function Latest_Date_Noted return Date_Type;

end Earliest_And_Latest;
```

## INSTRUCTOR NOTES

Month\_Type IS REFERRED TO LATER IN THE SPECIFICATION IN THE DECLARATION OF Date\_Type;  
Date\_Type IS REFERRED TO LATER IN THE SPECIFICATION IN THE DECLARATIONS OF THE  
SUBPROGRAMS.

AN ENTITY'S EXPANDED NAME CONSISTS OF THE NAME OF THE PACKAGE AND THE IDENTIFIER FOR THE  
ENTITY, SEPARATED BY A PERIOD. Earliest\_And\_Latest.Month\_Type, E.G., MEANS "THE ENTITY  
NAMED Month\_Type PROVIDED BY THE PACKAGE Earliest\_And\_Latest."

THE SLIDE LISTS EXPANDED NAMES FOR A TYPE, AN ENUMERATION VALUE, ANOTHER TYPE, AND A  
SUBPROGRAM PROVIDED BY PACKAGE Earliest\_And\_Latest.

# AN ENTITY DECLARED IN THE PACKAGE SPECIFICATION CAN BE REFERRED TO

- INSIDE THE PACKAGE: BY ITS IDENTIFIER
  - ANY PLACE IN THE PACKAGE SPECIFICATION FOLLOWING THE ENTITY'S  
DECLARATION
  - ANY PLACE IN THE CORRESPONDING PACKAGE BODY

Month\_Type

Date\_Type

- OUTSIDE THE PACKAGE: BY AN EXPANDED NAME

Earliest\_And\_Latest.Month\_Type

Earliest\_And\_Latest.January

Earliest\_And\_Latest.Date\_Type

Earliest\_And\_Latest.Note\_Date



## INSTRUCTOR NOTES

THIS PACKAGE BODY CONSISTS OF SIX DECLARATIONS, THE VARIABLE DECLARATIONS FOR Earliest So\_Far AND Latest So\_Far AND THE PROCEDURE BODIES FOR Is\_Earlier\_Than, Note\_Date, Earliest\_Date\_Noted, AND Latest\_Date\_Noted.

THE VARIABLES Earliest So\_Far AND Latest So\_Far COME INTO EXISTENCE WHEN THE PACKAGE COMES INTO EXISTENCE, AND STAY IN EXISTENCE FOR THE LIFETIME OF THE PACKAGE. IF ONE OF THE SUBPROGRAMS IN THE PACKAGE BODY LEAVES SOME VALUE IN ONE OF THOSE VARIABLES, THAT VALUE WILL BE THERE THE NEXT TIME ONE OF THOSE SUBPROGRAMS IS CALLED.

Earliest So\_Far AND Latest So\_Far ARE MAINTAINED BY Note\_Date SO THAT THEY INDICATE THE EARLIEST AND LATEST DATES SEEN SO FAR. THESE VARIABLES CANNOT BE REFERENCED FROM OUTSIDE OF THE PACKAGE BODY, WHICH GUARANTEES THAT THEY WILL KEEP THIS MEANING REGARDLESS OF WHAT HAPPENS OUTSIDE THE PACKAGE.

THE FUNCTION Is\_Earlier\_Than IS USED BY Note\_Date TO DETERMINE WHICH OF TWO DATES OCCURS BEFORE THE OTHER. IT IS PART OF THE PACKAGE'S IMPLEMENTATION RATHER THAN ITS INTERFACE. BECAUSE A SUBPROGRAM SPECIFICATION FOR Is\_Earlier\_Than DOES NOT OCCUR IN THE Earliest\_And\_Latest PACKAGE SPECIFICATION, IT MAY NOT BE CALLED FROM OUTSIDE THE PACKAGE BODY.

# EXAMPLE OF A PACKAGE BODY

```

package body Earliest_And_Latest is
    Earliest_So_Far: Date_Type := (December, 31);
    Latest_So_Far : Date_Type := (January, 1);
    -- global to package body
    -- global to package body

    function Is_Earlier_Than (Date_1, Date_2 : Date_Type) return Boolean is
    begin -- Is_Earlier_Than
        if Date_1.Month_Part < Date_2.Month_Part then
            return True;
        elsif Date_1.Month_Part = Date_2.Month_Part then
            return Date_1.Day_Part > Date_2.Day_Part;
        else -- Date_1.Month_Part < Date_2.Month_Part
            return False;
        end if;
    end Is_Earlier_Than;

    procedure Note_Date (Date: in Date_Type) is
    begin -- Note_Date
        if Is_Earlier_Than (Date, Earliest_So_Far) then
            Earliest_So_Far := Date;
        end if;
        if Is_Earlier_Than (Latest_So_Far, Date) then
            Latest_So_Far := Date;
        end if;
    end Note_Date;

    function Earliest_Date_Noted return Date_Type is
    begin -- Earliest_Date_Noted
        return Earliest_So_Far;
    end Earliest_Date_Noted;

    function Latest_Date_Noted return Date_Type is
    begin -- Latest_Date_Noted
        return Latest_So_Far;
    end Latest_Date_Noted;

    end Earliest_And_Latest;
-- Maintains Earliest_So_Far
-- and Latest_So_Far

```

## INSTRUCTOR NOTES

IF A PACKAGE PROVIDES ONLY TYPE, CONSTANT, OR VARIABLE DECLARATIONS, IT NEED NOT HAVE A PACKAGE BODY.

THE FIRST PACKAGE ON THIS SLIDE PROVIDES ONLY NAMED NUMBERS. A PROGRAM UNIT BEGINNING "WITH Metric\_Conversion;" CAN REFER TO Metric\_Conversion.Miles\_Per\_Meter AS IF IT WERE A REAL LITERAL.

THE SECOND PACKAGE DECLARES THE NAMED NUMBER Pi, THE FIXED POINT TYPES Distance AND Angle, AND SEVEN VARIABLES DESCRIBING THE CURRENT ORBIT AND POSITION OF A SATELLITE. ANY PROGRAM UNIT BEGINNING "with Orbit\_Status;" CAN EXAMINE OR SET THE VARIABLES Orbit\_Status.Major\_Semiasis, Orbit\_Status.Eccentricity, ETC. THESE VARIABLES ACT AS A COMMON DATABASE. THE PACKAGE Orbit\_Status BEHAVES VERY MUCH LIKE A FORTRAN NAMED COMMON BLOCK OR A JOVIAL COMPOOL.

CAVEAT: PACKAGES LIKE Orbit\_Status ARE GENERALLY A POOR USE OF PACKAGES. DATA SHOULD BE CLUSTERED WITH THE SUBPROGRAMS THAT USE IT.

# PACKAGES WITHOUT BODIES

```

package Metric_Conversion is
  Meters_Per_Mile : constant := 1609.0;
  Kilometers_Per_Mile : constant := Meters_Per_Mile/1000.0;
  Miles_Per_Meter : constant := 1.0/Meters_Per_Mile;
  Liters_Per_Gallon : constant := 4.546;
  Gallons_Per_Liter : constant := 1.0/Liters_Per_Gallon;
...
end Metric_Conversion;

package Orbit_Status is
  Pi : constant := 3.1415926535897932384626433;
  type Distance is delta 0.1 range 0.0 .. 50_000.0;
  type Angle is delta 0.001 range -Pi .. Pi;
  Major_Semiasis : Distance;
  Eccentricity : Float;
  Ascending_Node : Angle;
  Argument_Of_Perigee : Angle;
  Inclination : Angle;
  Current_Position : Angle;
end Orbit_Status;

```

## INSTRUCTOR NOTES

PACKAGE Factorial Package PROVIDES FACILITIES FOR THE EFFICIENT COMPUTATION OF FACTORIALS OF THE NUMBERS 0 THROUGH 20. THE PACKAGE PROVIDES A NAME FOR THE SUBTYPE OF VALID ARGUMENTS, AN INTEGER TYPE WITH A SUFFICIENTLY WIDE RANGE TO HOLD THE RESULT, AND A FUNCTION Factorial. THE CALL Factorial (X), WHERE  $0 < X < 20$ , RETURNS THE PRODUCT OF THE FIRST X INTEGERS. (THE PRODUCT OF ZERO INTEGERS IS 1.)

TO AVOID REDUNDANT MULTIPLICATION EACH TIME FACTORIAL IS INVOKED, A TABLE OF FACTORIALS IS SET UP WHEN THE PACKAGE FIRST COMES INTO EXISTENCE, AND THE FACTORIAL FUNCTION MERELY REFERENCES THIS TABLE. THE STATEMENTS BETWEEN "begin" AND "end Factorial Package" ARE EXECUTED ONCE, AT THE BEGINNING OF A PROGRAM USING THE PACKAGE Factorial Package, BEFORE CONTROL IS PASSED TO THE MAIN PROGRAM.

(BECAUSE THE TABLE IS PART OF THE IMPLEMENTATION OF THE PACKAGE, IT IS DECLARED IN THE PACKAGE BODY AND CAN'T BE USED DIRECTLY OUTSIDE THE PACKAGE BODY. THE INITIALIZATION STATEMENTS AND THE Factorial FUNCTION BODY ARE THE ONLY PARTS OF THE PROGRAM WITH ACCESS TO Table.)

(PARENTHETICAL NOTE ON INTEGER TYPES:  $20!$  IS APPROXIMATELY EQUAL TO  $2.4329 \times 10^{18}$ . THIS WILL BE GREATER THAN Integer'Last ON MOST IMPLEMENTATIONS, BUT COULD BE LESS THAN Long Integer'Last (THE VALUE FITS IN 64 BITS, BUT NOT IN 32). SINCE IT IS NOT SAFE TO HAVE Factorial RETURN A VALUE OF TYPE Integer, WE DEFINE A NEW INTEGER TYPE, Result\_Type. IT IS DECLARED TO BE SLIGHTLY LARGER THAN  $2.4329 \times 10^{18}$  TO MAKE SURE IT IS LARGE ENOUGH TO ACCOMMODATE THE VALUE OF  $20!$  AN Ada COMPILER WHICH CANNOT IMPLEMENT THE SPECIFIED RANGE WILL REJECT THE PACKAGE SPECIFICATION. THE ITERATION RULE OF THE FOR LOOP IMPLICITLY DECLARES I TO BE OF TYPE Integer, SO AN EXPLICIT CONVERSION IS REQUIRED TO MULTIPLY I BY Table (I-1), WHICH IS OF TYPE Result\_Type.)

# PACKAGE INITIALIZATION

```
package Factorial_Package is
  subtype Argument_Subtype is Integer range 0 .. 20;
  type Result_Type is range 1 .. 2443El5;
  function Factorial (N : Argument_Subtype) return Result_Type;
end Factorial_Package;

package body Factorial_Package is

  Table: array (Argument_Subtype) of Result_Type;

  function Factorial (N : Argument_Subtype) return Result_Type is
  begin -- Factorial
    return Table (N);
  end Factorial;

  begin -- Factorial_Package

    Table (0) := 1;
    for I in 1 .. Argument_Subtype'Last loop
      Table (I) := Table (I-1) * Result_Type (I);
    end loop;

  end Factorial_Package;
```

## INSTRUCTOR NOTES

A SEPARATELY COMPILED PACKAGE CAN BE USED IN ANOTHER COMPILATION UNIT THAT MENTIONS IT IN A with CLAUSE. A with CLAUSE CONSISTS OF THE RESERVED WORD with FOLLOWED BY A LIST OF COMPILATION UNIT NAMES SEPARATED BY COMMAS. THE with CLAUSE ENDS WITH A SEMICOLON. THIS SLIDE SHOWS TWO with CLAUSES, EACH NAMING ONLY ONE COMPILATION UNIT.

AT THE TOP OF THE SLIDE IS A SEPARATELY COMPILED FUNCTION THAT CONVERTS MILES PER GALLON TO KILOMETERS PER LITER. THE with CLAUSE ALLOWS THE FUNCTION TO USE RESOURCES PROVIDED BY THE PACKAGE Metric\_Conversion. THESE ARE REFERRED TO BY THEIR EXPANDED NAMES Metric\_Conversion.Kilometers\_Per\_Mile (IN THE ASSIGNMENT STATEMENT) AND Metric\_Conversion.Gallons\_Per\_Liter (IN THE RETURN STATEMENT).

AT THE BOTTOM OF THE SLIDE IS A SEPARATELY COMPILED FUNCTION THAT COMPUTES THE BINOMIAL COEFFICIENT OF  $n$  AND  $k$ , THE NUMBER OF DISTINCT COMBINATIONS OF  $k$  ITEMS THAT CAN BE EXTRACTED FROM A COLLECTION OF  $n$  ITEMS. THIS IS EQUAL TO  $n!/(k!(n-k)!)$ . THE with CLAUSE ALLOWS Binomial\_Coefficient TO USE RESOURCES PROVIDED BY Factorial\_Package. NOTE THE EXPANDED NAMES Factorial\_Package.Argument\_Subtype IN THE FUNCTION HEADING AND Factorial\_Package.Factorial IN THE RETURN STATEMENT. (THE / AND \* OPERATORS TAKE ARGUMENTS IN Factorial\_Package.Result\_Type AND PRODUCE RESULTS IN THAT TYPE. THE RESULT OF THE DIVISION IS THEN CONVERTED TO TYPE INTEGER. TYPICALLY, THE RIGHT OPERAND OF / IN THIS COMPUTATION IS QUITE LARGE SO THAT THE RESULT IS LESS THAN Integer'Last EVEN WHEN THE OPERANDS OF / ARE NOT.)

A COMPILATION UNIT BEGINNING "with Binomial\_Coefficient;" GETS ACCESS TO THIS FUNCTION, BUT IT DOES NOT GET ACCESS TO Factorial\_Package. THAT IS, with CLAUSES ARE NOT TRANSITIVE.

# USING PACKAGES

```
with Metric_Conversion;

function Kilometers_Per_Liter (Miles_Per_Gallon : Float) return Float is

    Kilometers_Per_Gallon : Float;

begin -- Kilometers_Per_Liter

    Kilometers_Per_Gallon :=
        Miles_Per_Gallon * Metric_Conversion.Kilometers_Per_Mile;
    return Kilometers_Per_Gallon * Metric_Conversion.Gallons_Per_Liter;

end Kilometers_Per_Liter;

-----

with Factorial_Package;

function Binomial_Coefficient (N, K: Factorial_Package.Argument_Subtype) return Integer is

begin -- Binomial_Coefficient
    return
        Integer
            (Factorial_Package.Factorial (N)/
             (Factorial_Package.Factorial (K) * Factorial_Package.Factorial (N-K)));
end Binomial_Coefficient;
```



## INSTRUCTOR NOTES

WHEN EXTENSIVE USE IS MADE OF THE RESOURCES PROVIDED BY A PACKAGE, EXPANDED NAMES CAN BECOME CUMBERSOME. A use CLAUSE ALLOWS ENTITIES DECLARED IN A SPECIFIED PACKAGE SPECIFICATION TO BE REFERRED TO BY SIMPLE NAMES (IDENTIFIERS) RATHER THAN EXPANDED NAMES.

THE use CLAUSE "USE Metric Conversion;" ALLOWS Metric Conversion.Kilometers Per Mile AND Metric\_Conversion.Gallons Per Liter TO BE REFERRED TO SIMPLY AS Kilometers\_Per\_Mile AND Gallons\_Per\_Liter WITHIN THE FUNCTION Kilometers\_Per\_Liter.

THE use CLAUSE "USE Factorial Package;" ALLOWS Factorial Package.Argument Subtype and Factorial Package.Factorial TO BE REFERRED TO SIMPLY AS Argument\_Subtype AND Factorial WITHIN THE FUNCTION Binomial\_Coefficients.

A use CLAUSE MAY OCCUR FOLLOWING A with CLAUSE (AS ON THIS SLIDE) OR WITHIN A SEQUENCE OF DECLARATIONS. IN GENERAL, THE RESERVED WORD use MAY BE FOLLOWED BY A LIST OF PACKAGES SEPARATED BY COMMAS.

IF A use CLAUSE WOULD LEAD TO MORE THAN ONE POSSIBLE INTERPRETATION FOR A GIVEN IDENTIFIER (FOR INSTANCE, IF Kilometers Per Liter HAD A LOCAL VARIABLE NAMED Kilometers\_Per\_Mile), THEN THE use CLAUSE DOES NOT APPLY TO THAT IDENTIFIER.

A use CLAUSE DOES NOT AFFECT WHICH ENTITIES YOU HAVE ACCESS TO, JUST THE WAY YOU NAME THOSE ENTITIES.

## USE CLAUSES

```
with Metric_Conversion; use Metric_Conversion;

function Kilometers_Per_Liter (Miles_Per_Gallon : Float) return Float is

    Kilometers_Per_Gallon : Float;

begin -- Kilometers_Per_Liter

    Kilometers_Per_Gallon := Miles_Per_Gallon * Kilometers_Per_Mile;
    return Kilometers_Per_Gallon * Gallons_Per_Liter;

end Kilometers_Per_Liter;
```

```
-----

with Factorial_Package; use Factorial_Package;

function Binomial_Coefficient (N, K : Argument_Subtype) return Integer is

begin -- Binomial_Coefficient

    return Integer (Factorial (N) / (Factorial (K) * Factorial (N-K)));

end Binomial_Coefficient;
```

## INSTRUCTOR NOTES

THE NAME `Argument_Subtype` BY ITSELF DOESN'T TELL US MUCH ABOUT THE MEANING OF THE SUBTYPE. THE EXPANDED NAME `Factorial_Package.Argument_Subtype` ANSWERS THE QUESTION

"ARGUMENT OF WHAT?"

IT IS A WITH CLAUSE THAT ALLOWS ENTITIES DECLARED IN SOME OTHER PACKAGE TO BE USED IN A COMPILATION UNIT. IT IS A USE CLAUSE THAT ALLOWS THE ENTITIES TO BE USED WITHOUT REFERRING TO THE PACKAGES THEY WERE DECLARED IN.

# PROBLEMS WITH use CLAUSE

- EXPANDED NAMES CAN BE INFORMATIVE

Argument\_Subtype VERSUS Factorial\_Package.Argument\_Subtype

- A use CLAUSE ALLOWS IDENTIFIERS DECLARED OUTSIDE A COMPILATION UNIT TO BE USED INSIDE A COMPILATION UNIT WITHOUT ANY INDICATION OF WHERE AND HOW THEY ARE DECLARED.

- WHEN A COMPILATION UNIT HAS with AND use CLAUSES FOR SEVERAL PACKAGES, IT IS DIFFICULT TO DETERMINE WHICH UNDECLARED IDENTIFIERS IN THE COMPILATION UNIT COME FROM WHICH PACKAGES.

INSTRUCTOR NOTES

FOR A PARTICULAR APPLICATION, THERE MAY BE OTHER PRIMITIVES WHOSE ORIGIN AND MEANING ARE OBVIOUS FROM THEIR NAME.

OPERATOR OVERLOADING IS DISCUSSED IN DETAIL LATER IN THE COURSE. STUDENTS SHOULD BE AT LEAST SUPERFICIALLY FAMILIAR WITH IT FROM PREVIOUS COURSES. AVOID GETTING INTO A DETAILED DISCUSSION NOW.

## WHEN TO USE use WITH with

- PACKAGES PROVIDING FAMILIAR NAMES OF BASIC PRIMITIVES

Get, Put

Sine, Cosine, Tangent

- PACKAGES PROVIDING NEW VERSIONS OF OPERATORS

- A PROGRAMMER CAN WRITE A TWO-PARAMETER FUNCTION NAMED "+", FOR EXAMPLE

- IF THIS FUNCTION IS PROVIDED BY A PACKAGE NAMED P, THE use CLAUSE

use P;

ALLOWS THE FUNCTION TO BE CALLED BY THE EXPRESSION

A + B

RATHER THAN

P."+"(A,B)



# RENAMING DECLARATIONS

- PROVIDE A NEW NAME FOR SOME ENTITY
- THE NEW NAME MAY BE MORE SUCCINCT OR MORE MEANINGFUL



# INSTRUCTOR NOTES

POINT OUT THE RENAMING DECLARATIONS IN THE SECOND VERSION.

IF THE FUNCTION HAD INCLUDED AN ASSIGNMENT TO `Date_1.Month_Part`, IT COULD HAVE BEEN  
REWRITTEN AS AN ASSIGNMENT TO `Month_1`.

# EXAMPLE OF RENAMING DECLARATIONS

## - ORIGINAL FUNCTION

```
function Is_Earlier_Than (Date_1, Date_2: Date_Type) return Boolean is
begin -- Is_Earlier_Than
    if Date_1.Month_Part < Date_2.Month_Part then
        return True;
    elsif Date_1.Month_Part = Date_2.Month_Part then
        return Date_1.Day_Part < Date_2.Day_Part;
    else -- Date_1.Month_Part > Date_2.Month_Part
        return False;
    end if;
end Is_Earlier_Than;
```

## - REWRITTEN WITH RENAMING DECLARATIONS:

```
function Is_Earlier_Than (Date_1, Date_2: Date_Type) return Boolean is
    Month_1 : Month_Type renames Date_1.Month_Part;
    Month_2 : Month_Type renames Date_2.Month_Part;
begin -- Is_Earlier_Than
    if Month_1 < Month_2 then
        return True;
    elsif Month_1 = Month_2 then
        return Date_1.Day_Part < Date_2.Day_Part;
    else -- Month_1 > Month_2
        return False;
    end if;
end Is_Earlier_Than;
```

## INSTRUCTOR NOTES

THE FIRST FORM IS USED FOR RENAMING A VARIABLE OR A CONSTANT.

THE SECOND FORM IS USED FOR RENAMING AN EXCEPTION.

THE THIRD FORM IS USED FOR RENAMING A PACKAGE. IT IS USEFUL FOR PACKAGES NESTED INSIDE OTHER PACKAGES. (ONE OF THE RESOURCES PROVIDED BY A PACKAGE MAY ITSELF BE A PACKAGE.)

THE FOURTH FORM IS USED FOR RENAMING A PROCEDURE OR FUNCTION.

THERE ARE NO RENAMING DECLARATIONS FOR TYPES OR SUBTYPES, BUT A SUBTYPE DECLARATION CAN BE USED TO ACHIEVE THE EFFECT OF RENAMING A TYPE OR SUBTYPE.

THE NEW NAME MAY, BUT NEED NOT, BE IDENTICAL TO PART OF THE OLD NAME.

# POSSIBLE FORMS OF RENAMING DECLARATIONS

```
Month_1: Month_Type renames Date_1.Month_Type;

Singular_Matrix: exception renames Matrix_Package.Singular_Matrix;

package Keypad_Interface renames Hardware_Interface.Keypad_Interface;

function Factorial (N: Argument_Subtype) return Result_Type
renames Factorial_Package.Factorial;

subtype Factorial_Argument_Subtype is Factorial_Package.Argument_Subtype;
```

## INSTRUCTOR NOTES

SOMETIMES IT IS BETTER TO USE SUBTYPE DECLARATIONS AND RENAMING DECLARATIONS INSTEAD OF  
use CLAUSES.

THE SUBTYPE DECLARATIONS DECLARE LOCAL SUBTYPES NAMED `Argument_Subtype` AND `Result_Type`  
WHICH CONSIST OF THE SAME VALUES AS `Factorial_Package.Argument_Subtype` AND  
`Factorial_Package.Result_Type`, RESPECTIVELY.

THE RENAMING DECLARATION FOR `Factorial` ESTABLISHES FACTORIAL AS A LOCAL NAME FOR THE  
FUNCTION `Factorial_Package.Factorial`. (THE RENAMING DECLARATION REFERS TO THE SUBTYPES  
DECLARED ABOVE IT. THE RETURN STATEMENT REFERS TO THE RENAMED FUNCTION.)

# USE OF RENAMING DECLARATIONS INSTEAD OF use CLAUSES

```
with Factorial_Package;

function Binomial_Coefficient (N, K: Factorial_Package.Argument_Subtype) return Integer is

    subtype Argument_Subtype is Factorial_Package.Argument_Subtype;
    subtype Result_Type is Factorial_Package.Result_Type;
    function Factorial (N: Argument_Subtype) return Result_Type
        renames Factorial_Package.Factorial;

begin -- Binomial_Coefficient

    return Integer (Factorial (N) / (Factorial (K) * Factorial (N-K)));

end Binomial_Coefficient;
```

## INSTRUCTOR NOTES

RENAMING DECLARATIONS REQUIRE FAR MORE WRITING THAN USE CLAUSES.

HOWEVER, THEY MAKE PROGRAMS FAR EASIER TO UNDERSTAND.

A BASIC PHILOSOPHY UNDERLYING ADA IS THAT EASE OF READING IS MORE IMPORTANT THAN EASE OF WRITING. A PROGRAM IS READ MANY MORE TIMES THAN IT IS WRITTEN.

# ADVANTAGES OF RENAMING DECLARATIONS

## ORDER use CLAUSES

- THERE IS A LOCAL DECLARATION DESCRIBING THE ENTITY
  - WHETHER IT IS A SUBPROGRAM, AN OBJECT, ETC.
  - THE PARAMETER AND RESULT TYPES OF A SUBPROGRAM, AMONG OTHER THINGS
  - THE TYPE OF AN OBJECT
- THE OLD NAME IN THE RENAMING DECLARATION TELLS WHERE THE ENTITY BEING RENAMED COMES FROM.
- ONE CAN RENAME JUST THE ENTITIES BEING USED RATHER THAN ALL ENTITIES PROVIDED BY SOME OTHER PACKAGE.
- ONE CAN PROVIDE A LOCALLY MORE MEANINGFUL NAME FOR THE ENTITY PROVIDED BY SOME GENERAL PURPOSE PACKAGE.



INSTRUCTOR NOTES

ALLOCATE AT LEAST ONE HOUR AND FIFTEEN MINUTES FOR LECTURE ON THIS SECTION.

ASSIGN EXERCISES 28 THROUGH 31 OF THE EXERCISE BOOKLET FOR LAB ASSIGNMENTS.

THE OBJECTIVE OF THIS SECTION IS TO INTRODUCE EXCEPTIONS, EXCEPTION HANDLING, AND THE BLOCK STATEMENT.

# **SECTION 14**

## **EXCEPTIONS**

VG 728.2



# DEFINITIONS

THIS CHAPTER DEFINES THE FACILITIES FOR DEALING WITH ERRORS OR OTHER EXCEPTIONAL SITUATIONS THAT ARISE DURING PROGRAM EXECUTION. SUCH A SITUATION IS CALLED AN EXCEPTION. TO RAISE AN EXCEPTION IS TO ABANDON NORMAL PROGRAM EXECUTION SO AS TO DRAW ATTENTION TO THE FACT THAT THE CORRESPONDING SITUATION HAS ARISEN. EXECUTING SOME ACTIONS, IN RESPONSE TO THE ARISING OF AN EXCEPTION, IS CALLED HANDLING THE EXCEPTION.

Ada LANGUAGE REFERENCE MANUAL

INSTRUCTOR NOTES

POINT OUT THAT Numeric\_Error WILL BE RAISED.

# EXCEPTION EXAMPLE

- WHEN DIVISOR IS ZERO AN EXCEPTION (CALLED Numeric\_Error) WILL OCCUR

```
procedure Example (Dividend, Divisor      : in Float;  
                  Partial_Result, Final_Result : out Float) is  
    . . .  
begin -- Example  
    . . .  
    Partial_Result := Dividend/Divisor;  
    . . .  
    Final_Result := Partial_Result + 1.0;  
end Example;
```

```
with Example;  
procedure Main is  
    A, B, C, D : Float;  
    . . .  
begin -- Main  
    . . .  
    Example (A, B, C, D);  
    . . .  
end Main;
```

INSTRUCTOR NOTES

THESE ARE OPTIONAL WAYS OF HANDLING AN EXCEPTION.

THIS IS A MOTIVATIONAL SLIDE TO SET THE STAGE.

THE CORRECTIVE ACTION THAT ONE MIGHT MAKE IS TO CLOSE UP A FILE OR PRINT A MESSAGE.

IF POSSIBLE DISPLAY 14-2 CONCURRENTLY.

# WHAT COULD BE DONE ?

- HANDLE THE EXCEPTIONS LOCALLY IN Example: SET Partial\_Result AND Final\_Result TO Float'Last AND RETURN TO PROCEDURE Main AS IF NOTHING UNUSUAL HAD HAPPENED
- OR
- TERMINATE EXECUTION OF PROCEDURE Example AND MAKE SITUATION KNOWN TO Main SO THAT IT CAN TAKE CORRECTIVE ACTION
- OR
- PASS THE PROBLEM TO THE OPERATING SYSTEM AND LET IT DO SOMETHING LIKE TERMINATE THE PROGRAM WITH AN ERROR MESSAGE
- 
- NONE OF THE ABOVE CHOICES IS RIGHT FOR EVERY APPLICATION
- SO
- Ada ALLOWS THE PROGRAMMER TO CONTROL THE HANDLING OF EXCEPTIONS



## INSTRUCTOR NOTES

THESE SLIDES ARE JUST TO SET MOTIVATION FOR THE NEED FOR Ada'S EXCEPTION HANDLING MECHANISM.

## ANOTHER EXCEPTION EXAMPLE

- WHEN DATA ENTERED DOES NOT MATCH TYPE OF OBJECT AN EXCEPTION WILL OCCUR

```
with Text_IO; use Text_IO;

procedure Expand_Command is

    type Input_Character_Type is (E, L, H, P, Q);
    Input_Character : Input_Character_Type;

    package Input_IO is new Enumeration_IO (Input_Character_Type);
    use Input_IO;

    ...

begin -- Expand_Command
    Get (Input_Character);

    ...

end Expand_Command;
```

INSTRUCTOR NOTES

QUESTION: HOW DO YOU KNOW WHAT STATEMENT RAISED AN EXCEPTION?

ANSWER: DEFINE YOUR OWN AND RAISE IT EXPLICITLY, OR ENCLOSE STATEMENT LIKELY TO RAISE EXCEPTIONS IN BLOCKS WITH HANDLERS. (THIS WILL BE SEEN SOON)

## IN GENERAL

- TO CONTROL THE HANDLING OF EXCEPTIONS WE'D LIKE TO

- 1) NAME EXCEPTIONAL SITUATIONS
- 2) CALL ATTENTION SOMEWHERE TO THE FACT THAT AN EXCEPTIONAL  
SITUATION OCCURRED
- 3) ATTEMPT TO CORRECT THE SITUATION

- THESE ACTIONS ARE MAPPED TO Ada CONSTRUCTS AS FOLLOWS:

- 1) EXCEPTION DECLARATION
- 2) raise STATEMENT
- 3) EXCEPTION HANDLER

INSTRUCTOR NOTES

CRC\_Failure STANDS FOR CYCLE REDUNDANCY CHECK FAILURE.

VG 728.2

14-61

JUN 22 1968 224 527 53A 421 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000

# USER-DEFINED EXCEPTIONS

## EXCEPTION DECLARATION

### SYNTAX:

```
Exception_Name | ,Exception_Name | : exception;
```

### EXAMPLES:

```
Division_By_Zero : exception;  
CRC_Failure      : exception;  
Sensor_Off       : exception;  
Hell             : exception;
```

INSTRUCTOR NOTES

THESE ARE DECLARED IN PACKAGE STANDARD. THEY ARE RAISED WHEN A RULE OF THE LANGUAGE IS VIOLATED DURING PROGRAM EXECUTION.

JUST READ THE NAMES AND INDICATE THAT EACH ONE IS COVERED ON THE NEXT SLIDES.



# PREDEFINED LANGUAGE EXCEPTIONS

THERE EXIST FIVE PREDEFINED LANGUAGE EXCEPTIONS:

- Constraint\_Error
- Numeric\_Error
- Program\_Error
- Storage\_Error
- Tasking\_Error



## INSTRUCTOR NOTES

1. "Tasking\_Error PERTAINS TO ACTIVATION OF TASKS, WHICH WILL BE DISCUSSED IN SECTION 14."
2. THESE DEFINITIONS, EXCERPTED FROM Ada LANGUAGE REFERENCE MANUAL, ARE INCOMPLETE, IN ACCORDANCE WITH THE SCOPE OF THIS MODULE.
3. NUMERIC-ERROR NEED NOT BE RAISED FOR TARGET MACHINES WHICH DO NOT ALLOW EASY DETECTION OF OVERFLOW CONDITIONS.
4. DISCRIMINANTS WILL BE DISCUSSED IN SECTION 14.

# PREDEFINED LANGUAGE EXCEPTIONS

- Constraint\_Error

THIS EXCEPTION IS RAISED IN THE FOLLOWING SITUATIONS (AMONG OTHERS):

- UPON AN ATTEMPT TO VIOLATE A RANGE CONSTRAINT, OR AN INDEX CONSTRAINT
- ASSIGNING 10 TO A VARIABLE DECLARED AS

X : Integer range 0 .. 5;

VIOLATES RANGE CONSTRAINT

- AN OUT OF BOUNDS SUBSCRIPT VIOLATES AN INDEX CONSTRAINT

- Numeric\_Error

THIS EXCEPTION IS RAISED BY THE EXECUTION OF A PREDEFINED NUMERIC OPERATION THAT CANNOT DELIVER THE CORRECT MATHEMATICAL RESULT, E.G. OVERFLOW OR ATTEMPTING TO DIVIDE BY ZERO

- AN IMPLEMENTATION IS NOT ALWAYS REQUIRED TO RAISE THIS EXCEPTION

## INSTRUCTOR NOTES

POINT OUT THAT THE COMPILER DOES NOT NEED TO CATCH INCORRECT ORDER DEPENDENCIES.

AN EXAMPLE OF THE FIRST POINT:

```
function F (B: Boolean) return Integer;  
A: Integer := F (True);  
function F (B: Boolean) return Integer is  
...  
begin -- F  
...  
end F;
```

AN EXAMPLE OF THE THIRD POINT IN Program\_Error IS

```
function F (B: Boolean) return Integer is  
X: Integer := 5;  
begin -- F  
  if B then  
    return X;  
  end if;  
end F;
```

CALLS TO F WITH ACTUAL PARAMETERS WITH VALUE False WILL RAISE Program\_Error.

# PREDEFINED LANGUAGE EXCEPTIONS (Continued)

- Program\_Error

THIS EXCEPTION IS RAISED UPON AN ATTEMPT:

- TO ACTIVATE A UNIT (FOR EXAMPLE TO CALL A SUBPROGRAM) WHOSE BODY HAS NOT YET BEEN ELABORATED
- DEPENDING ON THE IMPLEMENTATION, TO EXECUTE AN ACTION THAT IS ERRONEOUS
- TO EXIT A FUNCTION OTHER THAN BY A RETURN STATEMENT OR ANOTHER EXCEPTION.

- Storage\_Error

THIS EXCEPTION IS RAISED WHEN THERE IS INSUFFICIENT STORAGE (MEMORY) TO ALLOCATE NEW OBJECTS OR ACTIVATE NEW PROGRAM UNITS.

- Tasking\_Error

INSTRUCTOR NOTES

POINT OUT THAT THESE ARE JUST SOME OF THE SITUATIONS WHICH WILL CAUSE THE EXCEPTION TO OCCUR. FOR A COMPLETE LIST OF SITUATIONS FOR EACH OF THE LISTED EXCEPTIONS, REFER TO THE LRM.

POINT OUT THAT THESE EXCEPTIONS ARE IN THE PACKAGE IO\_exceptions.

THE EXCEPTIONS ARE COVERED IN MORE DEPTH IN CHAPTER 13.

# TEXT\_IO EXCEPTIONS

- Status\_Error

- RAISED ON AN ATTEMPT TO OPEN AN ALREADY OPEN FILE

- Mode\_Error

- RAISED ON AN ATTEMPT TO PERFORM AN OPERATION NOT APPLICABLE TO FILE  
MODE.

- Name\_Error

- RAISED ON AN ATTEMPT TO USE A NAME NOT LEGAL FOR AN EXTERNAL FILE

- Use\_Error

- RAISED ON AN ATTEMPT TO USE OPERATION NOT APPLICABLE TO EXTERNAL FILE

INSTRUCTOR NOTES

# TEXT\_IO EXCEPTIONS

- Device\_Error
  - RAISED BY MALFUNCTION OF HARDWARE
- End\_Error
  - RAISED ON AN ATTEMPT TO READ PAST END OF FILE
- Data\_Error
  - RAISED WHEN DATA IS NOT OF REQUIRED TYPE
- Layout\_Error
  - RAISED ON AN ATTEMPT TO SET COLUMN NUMBER IN EXCESS OF LINE LENGTH



## INSTRUCTOR NOTES

POINT OUT THAT:

raise;

IS USED IN EXCEPTION HANDLERS TO PROPAGATE THE EXCEPTION. PROPAGATE MEANS TO PASS THE EXCEPTION UP TO THE NEXT LEVEL FOR HANDLING.

RAISE STATEMENT MAY APPEAR IN THE EXECUTABLE PORTION OF PROCEDURES, FUNCTIONS AND PACKAGE BODIES.

POINT OUT THAT PREDEFINED EXCEPTIONS ARE AUTOMATICALLY RAISED BY THE LANGUAGE.

# RAISE STATEMENT

- PREDEFINED EXCEPTIONS AUTOMATICALLY RAISED BY LANGUAGE (OR Text\_IO)
- TO RAISE USER DEFINED EXCEPTIONS USE raise STATEMENT

## SYNTAX:

```
raise [Exception_Name];
```

## EXAMPLES:

```
raise Division_By_Zero;  
raise Hell;  
raise;           -- only in a handler  
raise Sensor_Off;
```

# INSTRUCTOR NOTES

POINT OUT THAT THE begin AND end COULD BELONG TO A BLOCK STATEMENT OR TO ANY PROGRAM UNIT. FOR EXAMPLE, THEY COULD BE IN A PROCEDURE, FUNCTION, PACKAGE BODY, TASK, OR GENERIC UNIT.

# EXCEPTION HANDLER

AN EXCEPTION HANDLER OCCURS IN A "FRAME"

```

      {
begin
    -- sequence of statements
exception
    -- exception handlers
end;

```

FRAME

INSTRUCTOR NOTES

# EXCEPTION HANDLER

A FRAME FOR AN EXCEPTION HANDLER CAN BE ANY OF THE FOLLOWING  
LANGUAGE CONSTRUCTS:

- SUBPROGRAM BODY
- BLOCK STATEMENT
- PACKAGE BODY

INSTRUCTOR NOTES

POINT OUT THAT STATEMENTS AFTER Get STATEMENT ARE NOT EXECUTED.

# EXCEPTION HANDLING EXAMPLE

```
with Text_IO; use Text_IO;

procedure Expand_Command is

    type Input_Character_Type is (E, L, H, P, Q);
    Input_Character : Input_Character_Type;

    package Input_IO is new Enumeration_IO (Input_Character_Type);
    use Input_IO;

    ...

begin -- Expand_Command
    Get (Input_Character);

    ...
    -- These statements not executed if
    -- Data_Error is raised

exception

    when Data_Error => Put_Line ("Invalid Entry");
                        Put_Line ("Try Again");

end Expand_Command;
```



INSTRUCTOR NOTES

"A BLOCK ALWAYS OCCURS INSIDE THE EXECUTABLE PART OF A PROGRAM UNIT. IT IS AN EXECUTABLE STATEMENT."

# BLOCK STATEMENT

- BLOCKS PROVIDE A MECHANISM FOR LOCALIZING EXCEPTION HANDLER(S)  
TO A STATEMENT OR SEQUENCE OF STATEMENTS

## SYNTAX:

```
[Block_Name:]  
[declare  
    local declarations;]  
begin -- Block_Name  
    sequence_of_statements;  
[exception  
    exception_handler;  
    {exception_handler;}]  
end [Block_Name];
```

- A BLOCK IS A STATEMENT

INSTRUCTOR NOTES

POINT OUT THAT NOW STATEMENTS AFTER Get CAN BE EXECUTED.

POINT OUT THAT THIS DOESN'T ALLOW FOR ANOTHER ATTEMPT BY THE Get STATEMENT. TO ALLOW RE-EXECUTION OF Get, THIS NEEDS TO BE PLACED WITHIN A LOOP.

## EXAMPLE WITH BLOCK

```
with Text_IO; use Text_IO;

procedure Better_Expand_Command is
    type Input_Character_Type is (E, L, H, P, Q);
    Input_Character : Input_Character_Type;
    package Input_IO is new Enumeration_IO (Input_Character_Type);
    use Input_IO;

    ...

begin -- Better_Expand_Command
    begin
        Get (Input_Character);
    exception
        when Data_Error => Put_Line ("Invalid Entry");
    end;

    ...
    -- These statements executed whether or not the
    -- exception Data_Error was raised

end Better_Expand_Command;
```

INSTRUCTOR NOTES

POINT OUT THAT NOW MULTIPLE ATTEMPTS ARE SUPPORTED.

## EXAMPLE ADDING LOOP WITH EXIT

```
with Text_IO; use Text_IO;
procedure Best_Expand_Command is
    type Input_Character_Type is (E, L, H, P, Q);
    Input_Character : Input_Character_Type;
    package Input_IO is new Enumeration_IO (Input_Character_Type);
    use Input_IO;
    ...
begin -- Best_Expand_Command
    loop
        begin
            Get (Input_Character);
            exit;
        exception
            when Data_Error => Put_Line ("Invalid Entry");
        end;
    end loop;
    ...
end Best_Expand_Command;
```

INSTRUCTOR NOTES

STRESS THAT others MUST APPEAR LAST AND AS THE ONLY CHOICE.

IE.

when Constraint\_Error | others =>

IS ILLEGAL. (SEE NEXT SLIDE.)

# MULTIPLE EXCEPTION CHOICES IN HANDLER

## SYNTAX:

```
when exception_choice ||exception_choice| =>  
    -- sequence of statements
```

## EXAMPLE:

```
begin  
    ...  
exception  
    when Division_By_Zero =>  
        -- sequence of statements  
        -- to be executed when Divisor = 0.0  
    when CRC_Failure =>  
        Recover_Message;  
    when others =>  
        -- sequence of statements to be executed when an  
        -- exception other than one of those listed above  
        -- is raised  
end;
```



INSTRUCTOR NOTES

# EXCEPTION HANDLER

others MUST BE THE LAST Exception\_Choice IN HANDLER AND MUST APPEAR AS ITS ONLY  
Exception\_Choice

```
-- LEGAL
begin
...
exception
  when Division_By_Zero =>
    ...
  when others =>
    ...
end;

-- **ILLEGAL
begin
...
exception
  when others =>
    ...
  when Division_By_Zero =>
    ...
end;

begin
...
exception
  when Division_By_Zero =>
    ...
  when others | CRC_Failure =>
    ...
end;
```

INSTRUCTOR NOTES

THIS CAN CAUSE PROBLEMS. THE CHOICE IN EXCEPTION HANDLERS NEEDS TO BE MANAGED EFFECTIVELY.

EMPHASIZE FOLLOWING WORDS: "ALL EXCEPTIONS," "INCLUDING," AND "NOT VISIBLE."

## OTHERS

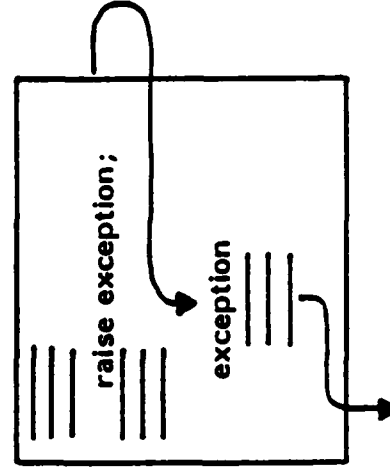
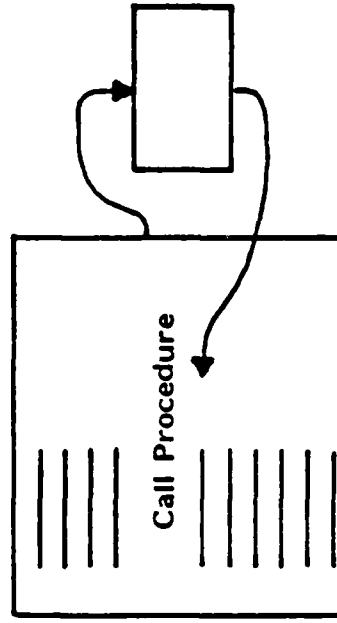
"STANDS FOR ALL EXCEPTIONS NOT LISTED IN PREVIOUS HANDLERS OF  
THE FRAME, INCLUDING EXCEPTIONS WHOSE NAMES ARE NOT VISIBLE  
AT THE PLACE OF THE EXCEPTION HANDLER."\*

\*LRM

## INSTRUCTOR NOTES

THE GENERAL RULE IS AFTER HANDLING, CONTROL LEAVES THE ENCLOSING FRAME.

EXAMPLE: UNLIKE PROCEDURE CALLS, WHEN AN EXCEPTION IS RAISED EXECUTION IS NOT RESUMED AT THE POINT AT WHICH IT WAS RAISED.



# EXCEPTION HANDLING CONTROL FLOW

- WHEN AN EXCEPTION IS RAISED, NORMAL PROGRAM EXECUTION IS SUSPENDED
- IF THERE IS A HANDLER FOR THE EXCEPTION IN THE INNERMOST FRAME, CONTROL IS TRANSFERRED TO IT
- IF THERE IS NO HANDLER, THE EXCEPTION IS PROPAGATED UP TO THE FRAME THAT CAUSED THE FRAME INCURRING THE EXCEPTION TO BE INVOKED -- THE CALLER IN THE CASE OF A SUBPROGRAM OR THE SURROUNDING FRAME IN THE CASE OF A BLOCK
- IF A HANDLER IS FOUND THERE IT IS EXECUTED. IF NOT, THE EXCEPTION IS PROPAGATED UP ONE MORE LEVEL
- IF NO HANDLER IS FOUND IN THE PROGRAM, THE UNDERLYING OPERATING SYSTEM TERMINATES THE PROGRAM (AND CAN TAKE OTHER ACTIONS SUCH AS ISSUING ERROR MESSAGES)
- WHEN A HANDLER IS FOUND, THE EXECUTION OF THE HANDLER REPLACES EXECUTION OF THE FRAME CONTAINING THE HANDLER (AND ANY LOWER LEVEL FRAMES)

# INSTRUCTOR NOTES

BE SURE TO POINT OUT WHERE `Division_By_Zero` IS DECLARED.

STRESS THAT IT IS NOT A PREDEFINED EXCEPTION.

THIS EXAMPLE IS CONTRIVED, BUT CONSIDER CHECKING FOR:

- DIVISION BY 0 + 0i IN A COMPLEX NUMBERS PACKAGE
- ATTEMPT TO INVERT A SINGULAR MATRIX

# EXAMPLE

## EXCEPTION HANDLING LOCALLY

```
procedure Example ( Dividend, Divisor      : in Float;
                    Partial_Result, Final_Result : out Float) is
    Division_By_Zero : exception;      -- exception declaration
begin -- Example
    . . .
    if Divisor = 0.0
    then
        raise Division_By_Zero;      -- raising the exception
    else
        Partial_Result := Dividend/Divisor;
    end if;
    . . .
    Final_Result := Partial_Result + 1.0;
exception
    when Division_By_Zero =>
        Partial_Result := Float'Last;
        Final_Result   := Float'Last;
end Example;
```



# INSTRUCTOR NOTES

POINT OUT THAT Main CATCHES ALL EXCEPTIONS. IT DOES NOT KNOW ABOUT Division\_By\_Zero.  
IT WAS DECLARED IN Example.

AN ALTERNATE WAY OF WRITING THIS EXAMPLE IS

```
package Pkg is
    Division_By_Zero: exception;
    procedure Example ...;
end Pkg;
with Pkg; use Pkg;
procedure Main is
    ...
exception
    when Division_By_Zero =>
        ...
end Main;
```

# EXAMPLE

## EXCEPTION PROPAGATED TO CALLER

```

procedure Example ( Dividend, Divisor      : in Float;
                    Partial_Result, Final_Result : out Float) is
    Division_By_Zero : exception;
begin -- Example
    . . .
    if Divisor = 0.0
    then
        raise Division_By_Zero;
    else
        Partial_Result := Dividend/Divisor;
    end if;
    . . . -- calculations
end Example;

with Example;
procedure Main is
    A, B, C, D : Float;
begin -- Main
    . . .
    Example (A, B, C, D);
    . . .

exception
    when others =>
        ... -- whatever
end Main;

```

-- these will not be executed if  
-- Division\_By\_Zero is raised in Example.  
-- Can be corrected with use of block  
-- construct as shown earlier.

INSTRUCTOR NOTES

POINT OUT THAT AFTER EXECUTING THE EXCEPTION HANDLER, EXECUTION CONTINUES WITH  
"REMAINING CALCULATIONS."

ASSIGN EXERCISES 28 THROUGH 31 OF THE LAB MANUAL.

ASSIGN CHAPTER 12 OF THE PRIMER.

# USING BLOCK TO LOCALIZE EXCEPTION HANDLING

```
with Example;  
procedure Main is  
    A, B, C, D : Float;  
    ...  
begin -- Main  
    ...  
begin -- BLOCK  
    Example (A, B, C, D);  
exception  
    when others =>  
        -- whatever  
end; -- BLOCK  
-- remaining calculations  
end Main;
```

# INSTRUCTOR NOTES

ALLOCATE ONE AND ONE HALF HOUR OF LECTURE FOR THIS SECTION. ASSIGN EXERCISE 32 OF THE EXERCISE BOOKLET FOR LAB ASSIGNMENT.

THE OBJECTIVE OF THIS SECTION IS TO INTRODUCE THE I/O OPERATIONS AVAILABLE IN Ada. EMPHASIS IS PLACED ON Text\_IO.

# **SECTION 15**

## **INPUT/OUTPUT**

## INSTRUCTOR NOTES

- STRESS THAT THE EXTERNAL FILE IS OUTSIDE THE PROGRAM.
- STRESS THAT IT CAN BE ANYTHING THAT CAN ACCEPT OR PRODUCE A CHARACTER

I.E., A CARD READER,  
TAPE,  
DISK FILE,  
I/O PORT

# I/O TERMINOLOGY

- EXTERNAL FILE - ANYTHING OUTSIDE THE PROGRAM THAT CAN PRODUCE A VALUE FOR INPUT OR ACCEPT A VALUE FOR OUTPUT.
- INTERNAL FILE - OBJECT WITHIN THE PROGRAM ABLE TO BE ASSOCIATED WITH AN EXTERNAL FILE.
- FILE - REFERS TO THE INTERNAL FILE
- OPEN FILE - INTERNAL FILE ASSOCIATED WITH AN EXTERNAL FILE
- CLOSED FILE - INTERNAL FILE NOT ASSOCIATED WITH AN EXTERNAL FILE



## INSTRUCTOR NOTES

- BASIC SCREEN LAID FIRST

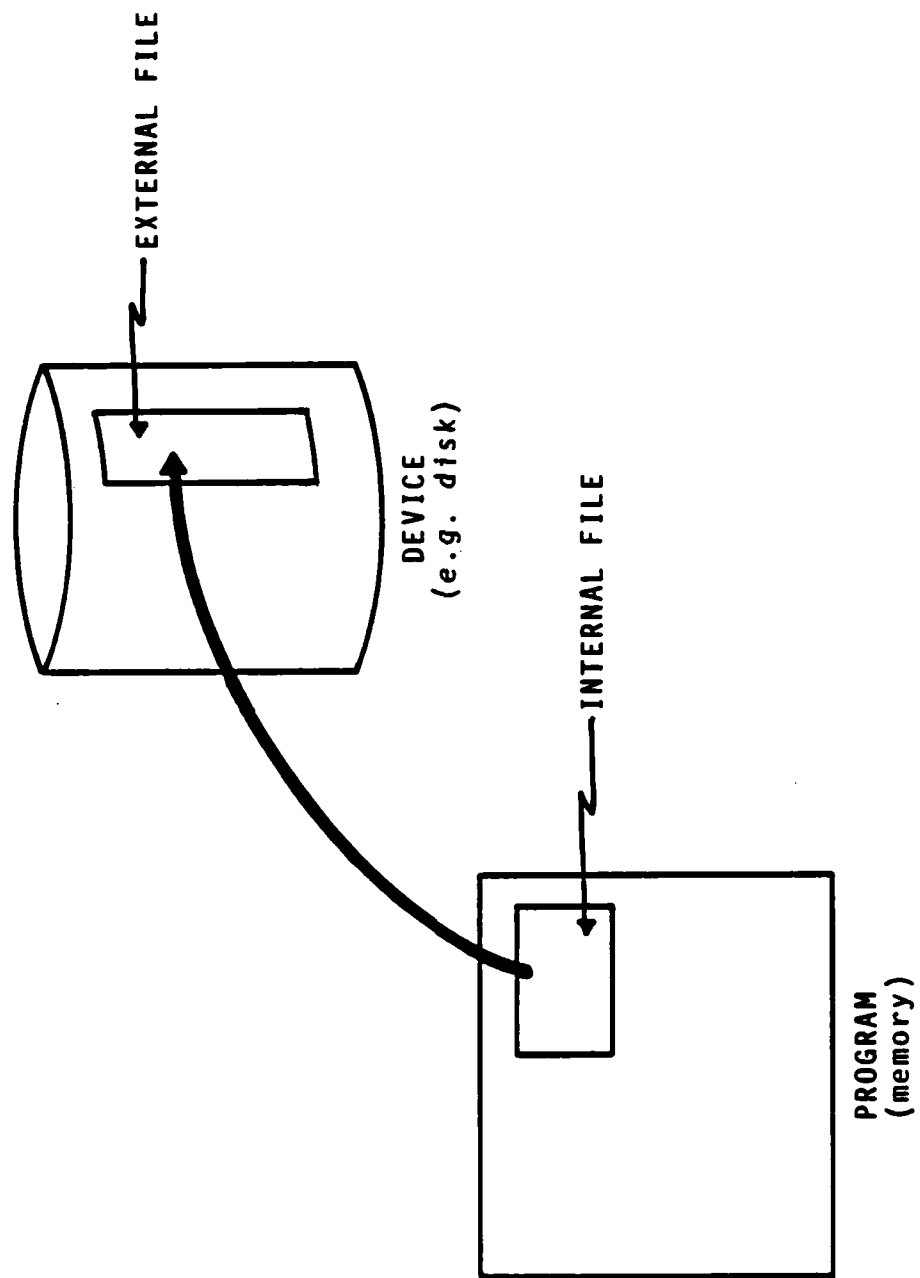
Identify External File

Identify Internal File

- LAY OVERLAY (ARROW) TO EXPLAIN AN OPEN FILE

STRESS THAT THE INTERNAL FILE IS THE ONE CONSIDERED OPEN

- REMOVE OVERLAY TO ILLUSTRATE CLOSING A FILE.



# INSTRUCTOR NOTES

- AN ISAM FILE IS A FORM OF RANDOM ACCESS FILE.
- EACH OF THESE IS A PREDEFINED LIBRARY UNIT WHICH MUST BE "WITH"ED TO BE USED.

# **I/O PACKAGES SUPPLIED BY LANGUAGE**

- **Text\_IO** - FOR I/O ON TEXTUAL (I.E. READABLE) FILES
- **Sequential\_IO** - FOR I/O ON SEQUENTIAL ACCESS FILES (EXAMPLE: TAPES)
- **Direct\_IO** - FOR I/O ON DIRECT ACCESS FILES (EXAMPLE: ISAM FILES)



## BASIC FILE COMMANDS

- Create
- Open
- Close
- Delete
- Reset

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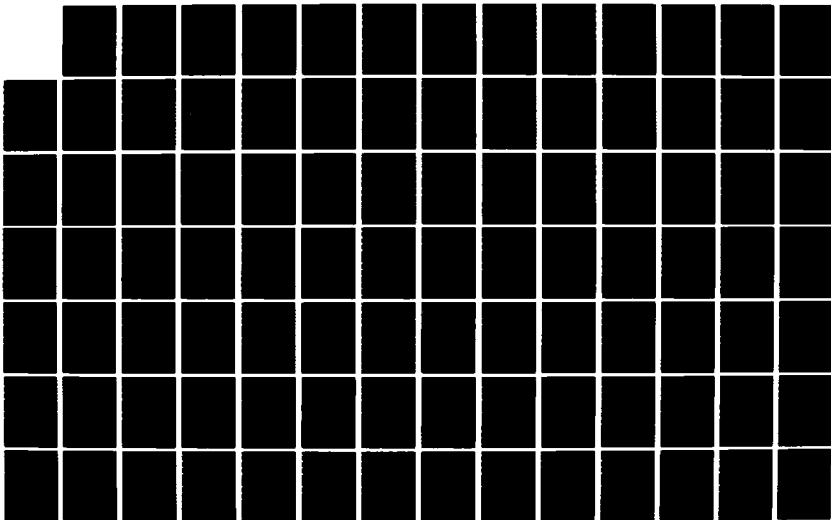
ADA (TRADE NAME) TRAINING CURRICULUM BASIC ADA  
PROGRAMMING L202 TEACHER'S GUIDE VOLUME 2(U) SOFTECH  
INC WALTHAM MA 1986 DAB07-83-C-K514

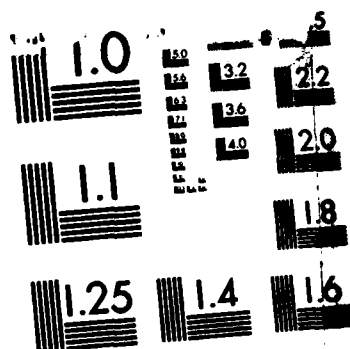
6/1

UNCLASSIFIED

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NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



# INSTRUCTOR NOTES

- STRESS THAT FORM WILL VARY - IT IS COMPLETELY IMPLEMENTATION DEPENDENT.
- MENTION THAT FORM IS INTENDED TO BE USED FOR SPECIFYING PERMISSIONS, SIZE LIMITS, ETC.
- File\_Mode IS AN ENUMERATION TYPE IN Text\_IO. ITS ENUMERATION LITERALS ARE In\_File AND Out\_File.

# THE Create COMMAND

```

procedure Create (File: in out File_Type;
  Mode: in File_Mode := Default_Mode;
  Name: in String := "";
  Form: in String := "M");
  • ESTABLISHES A NEW EXTERNAL FILE AND ASSOCIATES IT WITH AN INTERNAL FILE
  • PARAMETERS
    • File
      - THE INTERNAL FILE ASSOCIATED WITH THE NEWLY CREATED EXTERNAL
        FILE
    • Mode
      - DEFINES WHETHER THE FILE IS AN INPUT (In_File) OR AN
        OUTPUT (Out_File) FILE
      - THE Default_Mode IS Out_File FOR Text_IO AND Sequential_IO;
        Inout_File FOR Direct_IO
    • Name
      - IDENTIFIES THE EXTERNAL FILE
      - THE DEFAULT IS AN "UNNAMED" TEMPORARY EXTERNAL FILE
      - THIS FILE WILL CEASE TO EXIST WHEN THE PROGRAM TERMINATES
    • Form
      - SPECIFIES THE FILE FORM
      - WILL VARY FROM SYSTEM TO SYSTEM
      - WILL DEFAULT TO THE SYSTEM DEFAULT

```

# INSTRUCTOR NOTES

- POINT OUT THAT AS IN ALL PROCEDURE CALLS, THE PARAMETERS ARE SEPARATED BY COMMAS.
- Create creates a new external file, associates it with the internal file, and leaves the internal file open.
- THE EXAMPLE AT BOTTOM OF THE PAGE IS TO ILLUSTRATE WHAT COULD CAUSE Use\_Error TO BE RAISED.
- AN EXAMPLE OF RAISING Status\_Error IS WHEN YOU TRY TO ASSOCIATE THE SAME INTERNAL FILE WITH MORE THAN ONE EXTERNAL FILE.

# THE Create COMMAND (Continued)

## EXAMPLE

```
Data_File : File_Type;          -- THE PROCEDURE CREATE WILL GIVE Data_File
                                -- A VALUE
Create (File => Data_File,       -- CREATES A WRITE-ONLY FILE
       Mode => Out_File,        -- Data.Out. Form IS LEFT
       Name => "Data.Out");      -- WITH THE DEFAULT VALUE
```

NOTE: CREATE BOTH CREATES AND OPENS THE EXTERNAL FILE

## • EXCEPTIONS

- Status\_Error: WHEN THE INTERNAL FILE IS ALREADY OPEN
- Name\_Error: WHEN THE NAME STRING DOES NOT PROPERLY NAME A FILE
- Use\_Error: WHEN THE COMBINATION OF MODE, NAME, AND FORM DOES NOT  
ALLOW THE SYSTEM TO CREATE A FILE; FOR EXAMPLE:

CREATING A FILE WITH Mode Out\_File AND Form Read\_Only\_Access

INSTRUCTOR NOTES

# THE Open COMMAND

```

procedure Open (File: in out File_Type;
               Mode: in File_Mode;
               Name: in String;
               Form: in String := "");

```

- FUNCTION

OPENS AN INTERNAL FILE BY ASSOCIATING IT WITH AN EXISTING EXTERNAL FILE

- PARAMETERS

- File

- THE INTERNAL FILE TO BE ASSOCIATED WITH THE EXTERNAL FILE

- Mode

- THE MODE OF THE EXTERNAL FILE (In\_File, Out\_File, OR Inout\_File)  
 - THERE IS NO DEFAULT

- Name

- IDENTIFIES AN EXTERNAL FILE TO BE OPENED  
 - THERE IS NO DEFAULT

- Form

- SPECIFIES THE FILE FORM  
 - WILL VARY FROM SYSTEM TO SYSTEM  
 - WILL DEFAULT TO THE SYSTEM DEFAULT

# INSTRUCTOR NOTES

- STRESS THAT Open IS TO BE USED WHEN AN EXTERNAL FILE ALREADY EXISTS.
- EXPLAIN THAT TEMPORARY FILES CANNOT BE USED BY AN Open COMMAND. POINT OUT THAT THERE IS NO DEFAULT FOR Name. A NULL STRING WOULD RAISE Name\_Error.
- STRESS THAT YOU CANNOT OPEN AN INTERNAL FILE THAT IS ALREADY OPEN. I.E., IT IS ILLEGAL TO OPEN A FILE THAT HAS JUST BEEN USED IN A Create STATEMENT.
- THE EXAMPLE AT THE BOTTOM OF THE PAGE ILLUSTRATES HOW Use\_Error MIGHT BE RAISED.

# THE Open COMMAND (Continued)

## EXAMPLE

```
Test_File : File_Type;  
Open (File => Test_File,  
      Mode => In_File,  
      Name => "Test.Dat");
```

NOTE: OPEN DOES NOT FOLLOW THE CREATE COMMAND FOR THE SAME FILE

## • EXCEPTIONS

- Status\_Error: WHEN THE INTERNAL FILE IS ALREADY OPEN
- Name\_Error: WHEN THE NAME STRING DOES NOT IDENTIFY AN EXISTING FILE
- Use\_Error: WHEN THE COMBINATION OF Mode, Name, AND Form DOES NOT ALLOW THE SYSTEM TO OPEN THE FILE; FOR EXAMPLE:  
ATTEMPTING TO ASSOCIATE THE CARD READER TO A FILE  
WITH Mode Out\_File



INSTRUCTOR NOTES

"DELETES THE ASSOCIATION BETWEEN THE INTERNAL AND EXTERNAL FILE."

# THE Close COMMAND

procedure Close (File: in out File\_Type);

- FUNCTION

SEVERES THE ASSOCIATION BETWEEN THE INTERNAL AND EXTERNAL FILE

- PARAMETERS

- File

- INTERNAL FILE OBJECT TO BE CLOSED

## EXAMPLE

Close (Test\_File);

- EXCEPTIONS

- Status\_Error: RAISED WHEN THE INTERNAL FILE IS NOT OPEN

**INSTRUCTOR NOTES**

POINT OUT THAT FOR DELETE TO WORK, THE FILE MUST BE OPEN, I.E. THERE MUST BE A LINK BETWEEN THE INTERNAL FILE AND THE EXTERNAL FILE.

**"AFTER EXECUTING THE Delete COMMAND, THE EXTERNAL FILE SHOULD NO LONGER APPEAR IN YOUR DIRECTORY."**

**QUESTION: DOES DELETE DELETE ALL REVISIONS OF THE FILE?**

**ANSWER: THAT IS IMPLEMENTATION DEPENDENT.**

# THE Delete COMMAND

procedure Delete (File: in out File\_Type);

- FUNCTION

TO DELETE THE EXTERNAL FILE ASSOCIATED WITH THE GIVEN INTERNAL FILE AND  
CLOSE THE INTERNAL FILE

- PARAMETERS

- File

- THE INTERNAL FILE ASSOCIATED WITH THE EXTERNAL FILE TO BE  
DELETED

## EXAMPLE

Open (Junk\_File, In\_File, "Junk.Dat");  
Delete (Junk\_File);

- EXCEPTIONS

- Status\_Error: WHEN THE INTERNAL FILE IS NOT OPEN
- Use\_Error: WHEN THE EXTERNAL FILE CANNOT BE DELETED

# INSTRUCTOR NOTES

- STRESS THE NOTE, FILES OF Mode In\_File MAY BE RESET TO Mode Out\_File AND VICE VERSA.
- POINT OUT THAT THERE ARE TWO FORMS OF RESET. IT IS AN OVERLOADED PROCEDURE NAME.
- "RESET ALLOWS YOU TO OVERWRITE WHAT IS WRITTEN IN A FILE OR READ WHAT WAS JUST WRITTEN."

# THE Reset COMMAND

```
procedure Reset (File: in out File_Type;  
                Mode: in File_Mode);
```

```
procedure Reset (File: in out File_Type);
```

- FUNCTION

ALLOW READING FROM OR WRITING TO A FILE TO BE RESTARTED AT THE BEGINNING  
OF THE FILE

- PARAMETERS

- File

- THE INTERNAL FILE TO BE RESET

- Mode (IF SPECIFIED)

- THE Mode THE RESET FILE IS TO HAVE AFTER THE RESET

(NOTE: FILES OF Mode In\_File MAY BE RESET TO Mode Out\_File  
AND VICE VERSA)

EXAMPLE

```
Reset (Data_File, In_File);
```

# INSTRUCTOR NOTES

- THE EXAMPLE AT THE BOTTOM OF THE PAGE ILLUSTRATES HOW Use\_Error MIGHT BE RAISED.

# THE Reset COMMAND (Continued)

- EXCEPTIONS
  - Status\_Error: WHEN THE INTERNAL FILE IS NOT OPEN
  - Use\_Error: WHEN THE SYSTEM DOES NOT SUPPORT Reset AT ALL, OR WHEN RESETTNG TO THE SPECIFIED MODE FOR A GIVEN EXTERNAL FILE IS NOT SUPPORTED; FOR EXAMPLE:  
RESETTNG THE CARD READER TO Mode Out\_File



## INSTRUCTOR NOTES

THEY ARE COMMON TO THE THREE I/O PACKAGES ALSO. Status\_Error IS RAISED IF THE SPECIFIED FILE IS NOT OPEN.

- MODE - RETURNS THE MODE OF THE FILE. THE MODE CAN BE In\_File OR Out\_File FOR Text\_IO AND Sequential\_IO FILES. IT CAN BE In\_File, Out\_File, OR Inout\_File FOR Direct\_IO FILES.
- NAME - RETURNS THE NAME OF THE EXTERNAL FILE.
- FORM - RETURNS THE FILE'S FORM. THIS IS IMPLEMENTATION DEPENDENT. MAY CONTAIN INFORMATION SUCH AS ACCESS PERMISSIONS.
- Is\_Open - RETURNS TRUE IF THE INTERNAL FILE SPECIFIED IS ASSOCIATED WITH AN EXTERNAL FILE; FALSE OTHERWISE.

# COMMANDS FOR OBTAINING FILE INFORMATION

- function Mode (File: in File\_Type) return File\_Mode;
- function Name (File: in File\_Type) return String;
- function Form (File: in File\_Type) return String;
- function Is\_Open (File: in File\_Type) return Boolean;

## CONTEXT:

Data\_File : File\_Type;

## EXAMPLE:

```
if Is_Open (Data_File)
then
    Put (Data_File, "Hello");
end if;
```

## INSTRUCTOR NOTES

- AN EXAMPLE OF "HUMAN READABLE" IS A FILE GENERATED BY A TEXT EDITOR. A "NON-HUMAN READABLE" FILE WOULD BE A TAPE FILE.
- WITHOUT THE WITH CLAUSE, THE I/O SUBPROGRAMS WILL BE UNDEFINED. ALL PROGRAMS WHICH PERFORM I/O ON HUMAN READABLE FILES MUST IMPORT Text\_IO.
- THE DEFAULT FILES ARE DISCUSSED NEXT.
- Get AND Put ARE DISCUSSED IN DETAIL LATER.
- WE WILL SEE THE FORMATTING COMMANDS IN A FEW SLIDES.

# USING Text\_IO

- OPERATES ON HUMAN READABLE FILES
- MUST BE IMPORTED VIA A with CLAUSE  
EXAMPLE: with Text\_IO;
- HAVE DEFAULT FILES AND FORMATTING COMMANDS
- MAJOR OPERATIONS ARE Get AND Put

## INSTRUCTOR NOTES

- EXPLAIN THAT THE DEFAULT FILES ARE ASSOCIATED WITH FILES DEFINED BY THE IMPLEMENTATION. EXACTLY WHAT THEY ARE WILL VARY FROM IMPLEMENTATION TO IMPLEMENTATION.
- STRESS THAT THEY ARE OPEN AND CANNOT BE CLOSED OR RESET BY THE PROGRAMMER.
- EXPLAIN THAT IN FUTURE SLIDES WHEN THE PROCEDURE OR FUNCTION SPECIFICATION APPEARS WITHOUT A FILE PARAMETER, THAT PROCEDURE OR FUNCTION WILL BE OPERATING ON ONE OF THE CURRENT DEFAULT FILES.
- EXPLAIN THE DIFFERENCE BETWEEN CURRENT DEFAULT FILES AND STANDARD DEFAULT FILES.
- THE CURRENT DEFAULT FILES START OUT AS THE STANDARD DEFAULT FILES.
- THE STANDARD DEFAULT FILES CANNOT BE CHANGED
- THE CURRENT DEFAULT FILE CAN BE CHANGED (TO ANY OTHER FILE OF THE SAME MODE OR BACK TO THE STANDARD DEFAULT FILES)

# DEFAULT FILES

- CURRENT DEFAULT FILES

- CURRENT INPUT FILE - THE INPUT FILE USED WHEN NO FILE IS SPECIFIED  
IN OPERATIONS LIKE Get
- CURRENT OUTPUT FILE - THE OUTPUT FILE USED WHEN NO FILE IS SPECIFIED  
IN OPERATIONS LIKE Put

- STANDARD FILES

- STANDARD INPUT FILE - AN INPUT FILE OPEN AT THE BEGINNING OF THE PROGRAM  
(TYPICALLY THE TERMINAL KEYBOARD OR DATA CARDS IN A BATCH DECK)
- STANDARD OUTPUT FILE - AN OUTPUT FILE OPEN AT THE BEGINNING OF THE PROGRAM  
(TYPICALLY THE TERMINAL DISPLAY OR THE LINE PRINTER)

- INITIALLY, THE STANDARD INPUT AND OUTPUT FILES ARE THE SAME AS THE CURRENT DEFAULT FILES, BUT THE PROGRAM CAN CHANGE THE IDENTITY OF THE DEFAULT FILES.

## INSTRUCTOR NOTES

- SETS THE SPECIFIED FILE TO THE DEFAULT INPUT FILE  
I.E. MAKES IT THE CURRENT INPUT FILE.
- SETS THE SPECIFIED FILE TO THE DEFAULT OUTPUT FILE  
I.E. MAKES IT THE CURRENT OUTPUT FILE.
- RETURNS THE STANDARD INPUT FILE
- RETURNS THE STANDARD OUTPUT FILE
- RETURNS THE CURRENT INPUT FILE
- RETURNS THE CURRENT OUTPUT FILE
- MENTION THAT

My\_File := Standard\_Input;

IS ILLEGAL. THESE FUNCTIONS ARE INTENDED TO BE USED IN CONJUNCTION WITH OTHER I/O ROUTINES.

- THESE FUNCTIONS CAN BE USED AS PARAMETERS TO OTHER SUBPROGRAMS.
- TO Reset THE DEFAULT INPUT FILE TO Standard\_Input SAY Set\_Input (Standard\_Input);

# COMMANDS DEALING WITH DEFAULT FILES

- procedure Set\_Input (File: in File\_Type);
- procedure Set\_Output (File: in File\_Type);
- function Standard\_Input return File\_Type;
- function Standard\_Output return File\_Type;
- function Current\_Input return File\_Type;
- function Current\_Output return File\_Type;

## EXAMPLE:

```
Set_Input (Standard_Input);
```



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# Text\_IO COMMANDS FOR OBTAINING FILE INFORMATION

- function Line\_Length (File: in File\_Type) return Count;  
      \*function Line\_Length return Count;
- function Page\_Length (File: in File\_Type) return Count;  
      \*function Page\_Length return Count;
- function End\_Of\_Line (File: in File\_Type) return Boolean;  
      \*\*function End\_Of\_Line return Boolean;
- function End\_Of\_Page (File: in File\_Type) return Boolean;  
      \*\*function End\_Of\_Page return Boolean;
- function End\_Of\_File (File: in File\_Type) return Boolean;  
      \*\*function End\_Of\_File return Boolean;

\*OPERATES ON THE CURRENT OUTPUT FILE

\*\*OPERATES ON THE CURRENT INPUT FILE

type Count is range 0 .. <implementation defined>; -- defined in package Text\_IO  
IT IS IMPORTANT TO REALIZE THAT Count IS DEFINED AS A TYPE.

## INSTRUCTOR NOTES

- STRESS THAT THE DEFAULT FILE IS THE CURRENT OUTPUT FILE.
- MENTION THAT THESE COMMANDS MAY BE USED ON FILES OF MODE `In_File` OR `Out_File`.  
I.E. `Col (Standard_Input_File)`  
IS A LEGAL FUNCTION CALL.
- RESTATE THAT THE FILES MUST BE OPEN.
- POINT OUT THE TYPE Count. OBJECTS THAT ARE ASSIGNED `Page_Length` AND `Line_Length` MUST BE OF TYPE Count.

# **Text\_IO COMMANDS FOR OBTAINING FILE INFORMATION (Continued)**

- function Col (File: in File\_Type) return Positive\_Count;  
        \*function Col return Positive\_Count;
- function Line (File: in File\_Type) return Positive\_Count;  
        \*function Line return Positive\_Count;
- function Page (File: in File\_Type) return Positive\_Count;  
        \*function Page return Positive\_Count;

\*OPERATES ON THE CURRENT DEFAULT OUTPUT FILE

TYPE Positive\_Count IS A POSITIVE INTEGER, A SUBTYPE OF Count

# INSTRUCTOR NOTES

- STRESS THAT THESE OPERATE ON THE CURRENT OUTPUT FILE.
- MENTION THAT EACH OF THESE OPERATIONS MUST BE APPLIED TO A FILE OF MODE Out\_File.  
Mode\_Error IS RAISED OTHERWISE.
- RESTATE THAT THE FILE MUST BE OPEN.
- THERE ARE NO PREDEFINED SCREEN MANIPULATION COMMANDS.

# Text IO Operations on Files

- **procedure Set\_Line\_Length (File: in File\_Type;  
To: in Count);**
- **\*procedure Set\_Line\_Length (To: in Count);**

```
● procedure Set_Page_Length (File: in File_Type;  
                             To:    in Count);  
*procedure Set_Page_Length (To:    in Count);
```

```
●  procedure New_Line (File   : in File_Type;
                        Spacing: in Positive_Count := 1);
#procedure New_Line (Spacing: in Positive_Count := 1);
```

- **procedure New\_Page (File: in File\_Type);**  
**\*procedure New\_Page;**

**\*OPERATES ON THE CURRENT DEFAULT OUTPUT FILE**

## INSTRUCTOR NOTES

- STRESS WHICH DEFAULT FILE EACH OPERATION APPLIES TO.
- MENTION THAT EACH OPERATION CAN BE APPLIED TO FILES OF BOTH MODES: In\_File AND Out\_File.
- EXPLAIN Set\_Col  
FOR INPUT:  
READS AND DISCARDS CHARACTERS, LINE TERMINATORS, AND PAGE  
TERMINATORS UNTIL THE NEXT CHARACTER TO BE READ HAS A COLUMN NUMBER  
EQUAL TO THE SPECIFIED VALUE.  
FOR OUTPUT:  
OUTPUTS SPACES UNTIL THE CURRENT COLUMN NUMBER EQUALS THE SPECIFIED  
VALUE
- MENTION THAT THE OTHER OPERATIONS WORK SIMILARLY
- RESTATE THAT THE FILE MUST BE OPEN

## Text\_IO OPERATIONS ON FILES (Continued)

```
•      procedure Skip_Line (File:   in File_Type;  
                           Spacing: in Positive_Count := 1);  
      **procedure Skip_Line (Spacing: in Positive_Count := 1);  
  
•      procedure Skip_Page (File: in File_Type);  
      **procedure Skip_Page;  
  
•      procedure Set_Col (File: in File_Type;  
                        To:   in Positive_Count);  
      *procedure Set_Col (To:   in Positive_Count);  
  
•      procedure Set_Line (File: in File_Type;  
                        To:   in Positive_Count);  
      *procedure Set_Line (To:   in Positive_Count);  
  
      *OPERATES ON THE CURRENT DEFAULT OUTPUT FILE  
      **OPERATES ON THE CURRENT DEFAULT INPUT FILE
```



# INSTRUCTOR NOTES

- AN EXAMPLE OF Mode\_Error BEING RAISED WOULD BE Get FROM A FILE WITH MODE Out\_File.

- AN EXAMPLE OF Layout\_Error WOULD BE

Put (File1, MONDAY, 4);

WHERE MONDAY IS AN ENUMERATION LITERAL.

- AN EXAMPLE OF Data\_Error WOULD BE

type Day is (Monday, Tuesday, Wednesday, Thursday, Friday);

Day\_Of\_Week: Day;

.

.

.

Get (File1, Day\_Of\_Week);

WHEN File1 CONTAINS

Saturday

# Get AND Put PROCEDURES

- EXIST FOR:

- CHARACTER TYPES
- STRING TYPES
- INTEGER TYPES
- FIXED POINT TYPES
- FLOATING POINT TYPES
- ENUMERATION TYPES

- EXCEPTIONS

- BOTH RAISE Status\_Error WHEN THE INTERNAL FILE IS NOT OPEN
- BOTH RAISE Mode\_Error WHEN THE MODE IS NOT CORRECT FOR THE OPERATION
- Get RAISES End\_Error IF IT TRIES TO READ PAST THE END OF THE FILE
- Put RAISES LAYOUT\_ERROR IF IT CANNOT FIT THE CHARACTER REPRESENTATION OF THE VALUE IN THE SPACE PROVIDED
- GET RAISES Data\_Error IF THE VALUE OF THE ITEM IS OF AN INCORRECT

TYPE

## INSTRUCTOR NOTES

- POINT OUT THAT Get OPERATES ON THE CURRENT INPUT FILE WHEN NO FILE IS SPECIFIED
- EXPLAIN THE DIFFERENCES BETWEEN Get (WHERE ITEM IS A STRING) AND Get\_Line
  - Get (WHEN ITEM IS A STRING), FILLS THE STRING, IGNORING LINE AND PAGE TERMINATORS. IF N IS THE LENGTH OF THE STRING, N CHARACTERS ARE READ.
  - Get\_Line READS UNTIL A LINE TERMINATOR IS THE NEXT CHARACTER TO BE READ, OR UNTIL N CHARACTERS ARE READ, WHICHEVER INVOLVES THE LEAST AMOUNT OF GETS.

# Character AND String Get

- procedure Get (File: in File\_Type;  
Item: out Character);  
procedure Get (Item: out Character);
- procedure Get (File: in File\_Type;  
Item: out String);  
procedure Get (Item: out String);
- procedure Get\_Line (File: in File\_Type;  
Item: out String;  
Last: out Natural);  
procedure Get\_Line (Item: out String;  
Last: out Natural);

Last IS THE INDEX VALUE IN THE STRING OF THE LAST CHARACTER READ.

# INSTRUCTOR NOTES

- POINT OUT THAT Put OPERATES ON THE CURRENT OUTPUT FILE WHEN NO FILE IS SPECIFIED
- EXPLAIN THE DIFFERENCE BETWEEN Put WHERE ITEM IS A STRING AND Put\_Line
  - Put WHEN ITEM IS A STRING OUTPUTS EACH CHARACTER IN THE STRING. THE STRING CAN SPAN OVER SEVERAL LINES IF THE LINES ARE BOUNDED (I.E. Set\_Line\_Length HAS BEEN CALLED) AND THE STRING IS LONGER THAN THE LINE LENGTH. NO LINE TERMINATORS ARE AUTOMATICALLY OUTPUT.
  - Put\_Line OUTPUTS THE STRING ON A SINGLE LINE, FOLLOWED BY A LINE TERMINATOR. THE STRING MUST FIT ON A SINGLE LINE. Layout\_Error IS RAISED OTHERWISE.

# Character AND String Put

- procedure Put (File: in File\_Type;  
                    Item: in Character);  
  
      procedure Put (Item: in Character);
- procedure Put (File: in File\_Type;  
                    Item: in String);  
  
      procedure Put (Item: in String);
- procedure Put\_Line (File: in File\_Type;  
                          Item: in String);  
  
      procedure Put\_Line (Item: in String);

## INSTRUCTOR NOTES

- Integer\_IO IS A GENERIC PACKAGE CONTAINED IN Text\_IO.
- Get AND Put WORK PRIMARILY THE SAME WAY AS FOR Character AND String.
- STRESS THE DIFFERENCES
- POINT OUT THAT Get CAN "READ" A VALUE FROM A STRING. Last WORKS THE SAME WAY.
- WHEN NO FILE IS SPECIFIED THE CURRENT DEFAULT FILE IS USED.
- EXAMPLE OF READING FROM A STRING  
    Get ("45 ", item, last);  
ITEM WILL EQUAL 45  
LAST WILL EQUAL 2
- A WIDTH OF 0 MEANS "READ THE LONGEST SEQUENCE OF CHARACTERS THAT CAN BE INTERPRETED AS A NUMBER." IT IS THE WIDTH USED WHEN NONE IS SPECIFIED IN A CALL.

# Get AND Put FOR Integer TYPES

TO ALLOW I/O OF Integer TYPE Int WRITE:

```
package Int_IO is new Integer_IO (Int); use Int_IO;
```

THIS GIVES THE FOLLOWING:

- GET OPERATIONS

- procedure Get (File: in File\_Type;  
Item: out Num;  
Width: in Field := 0);
- procedure Get (Item: out Num;  
Width: in Field := 0);

- procedure Get (From: in String;  
Item: out Num;  
Last: out Positive);

TYPE Field IS A NON-NEGATIVE INTEGER SUBTYPE.



## INSTRUCTOR NOTES

- POINT OUT THAT PUT CAN "WRITE" A VALUE INTO A STRING
- RESULT IS RIGHT JUSTIFIED
- STRESS THAT Int IS Num
- EXPLAIN UNBOUNDED VS. BOUNDED.  
UNBOUNDED - NO SPECIFIED FORMAT  
BOUNDED - VALUE MUST BE EXPRESSED IN WIDTH SPACES
- MENTION THAT Default\_Base AND Default\_Width CAN BE MODIFIED
- EXAMPLE  
STR : String (1 .. 5);  
...  
Put (STR, 31, Base => 10);  
  
STR WILL BE " 31".

# Get AND Put FOR Integer TYPES (Continued)

```
• Put OPERATIONS
  • procedure Put (File: in File_Type;
    Item: in Num;
    Width: in Field := Default_Width;
    Base: in Number_Base := Default_Base);

  procedure Put (Item: in Num;
    Width: in Field := Default_Width;
    Base: in Number_Base := Default_Base);

  • procedure Put (To: out String;
    Item: in Num;
    Base: in Number_Base := Default_Base);
```

NOTE: Num IS WHATEVER TYPE APPEARS IN THE DECLARATION; IN THIS CASE Int.  
Default\_Width IS ZERO, I.E. "UNBOUNDED"  
Default\_Base IS TEN

NOTE: FOR EACH INTEGER TYPE THE PROGRAMMER DEFINES, HE MUST WRITE  
THIS INSTANTIATION IN THE DECLARATIVE PART:  
package Package\_Name is new Integer\_IO (Integer\_Type\_Name);  
use Package\_Name;

# INSTRUCTOR NOTES

- Fixed\_IO AND Float\_IO ARE GENERIC PACKAGES CONTAINED IN Text\_IO
- RESTATE THAT Put AND Get WORK THE SAME AS FOR Characters AND Strings
- POINT OUT THAT THESE ALSO OPERATE ON Strings AS WELL AS Files.
- POINT OUT THAT NUM IS THE GENERIC TYPE PARAMETER.

# Get AND Put FOR Fixed AND Float TYPES

TO ALLOW I/O FOR FLOATING POINT TYPE Flt, WRITE:

```
package Flt_IO is new Float_IO (Flt);  
use Flt_IO;
```

TO ALLOW I/O FOR FIXED POINT TYPE Fix WRITE:

```
package Fix_IO is new Fixed_IO (Fix);  
use Fix_IO;
```

THIS GIVES THE FOLLOWING:

- Get OPERATIONS
  - procedure Get (File: in File\_Type;  
Item: out Num;  
Width: in Field := 0);  
  
procedure Get (Item: out Num;  
Width: in Field := 0);
- procedure Get (From: in String;  
Item: out Num;  
Last: out Positive);

# INSTRUCTORS NOTES

- NOTICE THAT YOU CAN SPECIFY THE WIDTH FOR BEFORE THE DECIMAL POINT (Fore), AFTER THE DECIMAL POINT (Aft), AND FOR THE EXPONENT (Exp).

# Get AND Put FOR Fixed AND Float TYPES (Continued)

```
• Put OPERATIONS
• procedure Put (File: in File_Type;
  Item: in Num;
  Fore: in Field := Default_Fore;
  Aft: in Field := Default_Aft;
  Exp: in Field := Default_Exp);

  procedure Put (Item: in Num;
    Fore: in Field := Default_Fore;
    Aft: in Field := Default_Aft;
    Exp: in Field := Default_Exp);

• procedure Put (Io: out String;
  Item: in Num;
  Aft: in Field := Default_Aft;
  Exp: in Field := Default_Exp);
```

INSTRUCTOR NOTES

# Get AND Put FOR Fixed AND Float TYPES (Continued)

NOTE: Num IS THE TYPE USED IN THE I/O DECLARATION, E.G., Flt OR Fix.

FOR Float\_IO

Default\_Fore IS 2

Default\_Aft IS Num'Digits -1

Default\_Exp IS 3

FOR Fixed\_IO

Default\_Fore IS Num'Fore

Default\_Aft IS Num'Aft

Default\_Exp IS ZERO



## INSTRUCTOR NOTES

- Enumeration\_IO IS A GENERIC PACKAGE CONTAINED IN Text\_IO.
- RESTATE THAT THEY WORK JUST LIKE Get and Put for CHARACTERS.
- POINT OUT THAT THESE ALSO WILL OPERATE ON STRINGS AS WELL AS FILES.

# Get AND Put FOR ENUMERATION TYPES

TO ALLOW I/O OF ENUMERATION TYPE Enum, WRITE:

```
package Enum_IO is new Enumeration_IO (Enum); use Enum_IO;
```

THIS GIVES THE FOLLOWING:

- Get OPERATIONS
  - procedure Get (File: in File\_Type;  
Item: out Enum);
  - procedure Get (Item: out Enum);
- procedure Get (From: in String;  
Item: out Enum;  
Last: out Positive);

## INSTRUCTOR NOTES

- HERE NOTICE THAT YOU CAN SPECIFY THE CASE OF THE OUTPUT.
- "WE HAVE NOW COVERED Text\_10."

# Get AND Put FOR ENUMERATION TYPES (Continued)

- Put OPERATIONS

- procedure Put (File: in File\_Type;

- Item: in Enum;

- Width: in Field := Default\_Width;

- Set: in Type\_Set := Default\_Setting);

- procedure Put (Item: in Enum;

- Width: in Field := Default\_Width;

- Set: in Type\_Set := Default\_Setting);

- procedure Put (To: out String;

- Item: in Enum;

- Set: in Type\_Set := Default\_Setting);

Default\_Width IS ZERO

Default\_Setting IS Upper\_Case

(OTHER CHOICE IS Lower\_Case)

# INSTRUCTOR NOTES

- Read AND Write WILL BE EXPLAINED IN DETAIL IN THE NEXT TWO SLIDES.
- POINT OUT THAT Sequential\_IO CAN TECHNICALLY BE INSTANTIATED WITH ANY TYPE, BUT EACH IMPLEMENTATION WILL DECIDE WHICH TYPES TO SUPPORT (I.E. UNCONSTRAINED ARRAY TYPES MAY NOT BE SUPPORTED).
- REMIND THEM THAT THE MODES FOR Sequential\_IO ARE In\_File AND Out\_File.
- THE CURRENT INDEX POINTS TO THE NEXT LOCATION THE I/O OPERATION WILL ACT ON.  
(I.E. POINT TO THE NEXT ITEM TO BE READ OR TO THE PLACE THE NEXT ITEM WILL BE WRITTEN.)

# USING Sequential\_IO

- ALLOWS BINARY INPUT/OUTPUT ON SEQUENTIAL ACCESS FILES.
- IS A LIBRARY UNIT AND MUST BE IMPORTED VIA A with CLAUSE  
EG: with Sequential\_IO;
- IS A GENERIC PACKAGE AND MUST BE INSTANTIATED WITH A type.  
type Array\_Type is array (1 .. 10) of Boolean;  
package Arr\_IO is new Sequential\_IO (Array\_Type);  
use Arr\_IO;
- HAS A "CURRENT INDEX" WHICH IS SEQUENTIALLY INCREMENTED.
- MAJOR OPERATIONS ARE Read AND Write

# INSTRUCTOR NOTES

- Element\_Type IS WHATEVER TYPE THE PACKAGE WAS INSTANTIATED WITH.
- THE EXAMPLE DOES NOT SHOW THE Open. THE FILE MUST HAVE BEEN OPENED WITH MODE In\_File.

# Sequential\_IO OPERATIONS

```
procedure Read (File : in File_Type;  
               Item : out Element_Type);
```

- FUNCTION

RETURNS THE NEXT VALUE OF TYPE Element\_Type FROM THE SPECIFIED FILE.  
OPERATORS OF FILES OF MODE In\_File.

- EXCEPTIONS

Status\_Error, RAISED WHEN THE FILE IS NOT OPEN.  
Mode\_Error, RAISED WHEN THE MODE IS NOT In\_File.  
Data\_Error, RAISED WHEN THE VALUE READ IS NOT OF TYPE Element\_Type.

- CONTEXT

```
type Array_Type is array (1 .. 10) of Boolean;  
Boolean_Array : Array_Type;  
package Arr_IO is new Sequential_IO (Array_Type);  
use Arr_IO;  
Bool_File : File_Type;
```

- EXAMPLE

```
Read (Bool_File, Boolean_Array);
```



## INSTRUCTOR NOTES

- Sequential\_IO IS A GENERIC PACKAGE. IT IS INSTANTIATED WITH TYPES TO DO I/O ON OBJECTS OF THOSE TYPES. REMIND THEM THAT IT IS A LIBRARY UNIT WHICH MUST BE "with\*ED."
- Sequential\_IO IS USED ON SEQUENTIAL ACCESS FILES (TAPE)
- Sequential\_IO USES Read AND Write INSTEAD OF Get AND Put. THESE OPERATIONS WILL BE DISCUSSED IN DETAIL ON THE FOLLOWING SLIDES.
- REMIND THEM THAT Create, Open, Close, Delete, Reset, Mode, Name, Form, AND Is\_Open ARE DEFINED IN Sequential\_IO.
- REMIND THEM THAT In\_File AND Out\_File ARE THE ALLOWABLE MODES FOR Sequential\_IO FILES.

# Sequential\_IO OPERATIONS

procedure Write (File : in File\_Type; Item : in Element\_Type);

- FUNCTION

OUTPUTS THE VALUE OF ITEM AT THE END OF THE FILE.  
OPERATES ON FILES OF MODE Out\_File.

- EXCEPTIONS

Status\_Error, RAISED WHEN THE SPECIFIED FILE IS NOT OPEN  
Mode\_Error, RAISED WHEN THE MODE IS NOT Out\_File

- CONTEXT

type Array\_Type is array (1 .. 10) of Boolean;  
Boolean\_Array : Array\_Type := (True, True, False, False, True, True, False, True, True, False,  
True, False, True);  
package Arr\_IO is new Sequential\_IO (Array\_Type);  
use Arr\_IO;  
Bool\_File : File\_Type;

- Example

Write (Bool\_File, Boolean\_Array);

## INSTRUCTOR NOTES

- THIS COMPLETES THE COMMANDS FOR Sequential\_IO.
- IN THE EXAMPLE, File\_End WOULD BE A USER DEFINED EXCEPTION.

# Sequential\_IO OPERATIONS

function End\_Of\_File (File : File\_Type) return Boolean;

- FUNCTION

RETURNS TRUE IF NO MORE ELEMENTS CAN BE READ FROM THE FILE: FALSE OTHERWISE.  
OPERATES ON FILES OF MODE In\_File.

- EXCEPTIONS

Status\_Error, RAISED WHEN THE FILE IS NOT OPEN  
Mode\_Error, RAISED WHEN THE MODE IS NOT In\_File.

- CONTEXT

File\_End : exception;

- EXAMPLE

```
if End_Of_File (Bool_File) then
    raise File_End;
else
    Read (Bool_File, Boolean_Array);
    .
    .
    .
end if;
```

## INSTRUCTOR NOTES

- Read AND Write ARE EXPLAINED IN DETAIL IN THE FOLLOWING SLIDES.
- THEY ARE SLIGHTLY DIFFERENT THAN Read AND Write FOR Sequential\_IO.
- Direct\_IO CAN ALSO BE INSTANTIATED WITH ANY TYPE, BUT IMPLEMENTATIONS ARE NOT REQUIRED TO SUPPORT THEM.
- THE MODES FOR Direct\_IO ARE In\_File, Out\_File, AND Inout\_File.
- WE WILL LATER SEE THE COMMANDS TO CHANGE THE CURRENT INDEX. REMIND THEM WHAT THE CURRENT INDEX IS.

# USING Direct\_IO

- ALLOWS BINARY INPUT/OUTPUT ON DIRECT ACCESS FILES
- IS A LIBRARY UNIT WHICH MUST BE IMPORTED VIA A WITH CLAUSE  
EXAMPLE: with Direct\_IO;
- IS A GENERIC PACKAGE WHICH MUST BE INSTANTIATED WITH A TYPE  
EXAMPLE: type Array\_Type is array (1 .. 10) of Boolean;  
package Arr\_IO is new Direct\_IO (Array\_Type);  
use Arr\_IO;
- MAJOR OPERATIONS ARE Read AND Write
- HAS A CURRENT INDEX WHICH CAN BE DIRECTLY CHANGED

# INSTRUCTOR NOTES

- Element\_Type IS WHATEVER TYPE Direct\_IO WAS INSTANTIATED WITH
- IN THE EXAMPLE, THE FILE MUST HAVE BEEN OPENED WITH MODE In\_File OR Inout\_File.
- IN THE EXAMPLE, THE THIRD "RECORD" WOULD BE READ AND ASSIGNED TO RESULT.
- End\_Error WOULD BE RAISED IF FROM HAD BEEN GREATER THAN 5.
- THE MISSING CODE FOR THE EXAMPLE IS:  
package Bool\_IO is new Direct\_IO (Boolean);  
use Bool\_IO;  
File : File\_Type;  
.  
.  
.  
Open (File, In\_File, "Data.Fil");
- THEY HAVE SEEN Positive\_Count IN Text\_IO.

# Direct\_IO OPERATIONS

```
procedure Read (File : in File_Type;  
               Item : out Element_Type;  
               From : in Positive_Count);
```

```
procedure Read (File : in File_Type;  
               Item : out Element_Type);
```

- FUNCTION

RETURNS THE VALUE LOCATED AT THE POSITION SPECIFIED BY THE Current\_Index.  
(THE VALUE OF FROM, IF SPECIFIED: THE NEXT VALUE OTHERWISE)

- EXCEPTIONS

Status\_Error, RAISED IF THE FILE IS NOT OPEN

Mode\_Error, RAISED IF THE MODE IS NOT In\_File OR Inout\_File.

Data\_Error, RAISED IF THE VALUE READ IS NOT OF TYPE Element\_Type

End\_Error, RAISED WHEN AN ATTEMPT IS MADE TO READ PAST THE END OF THE FILE.

- EXAMPLE

```
File:  
TRUE  
FALSE  
TRUE ← Result  
TRUE  
FALSE  
Result: Boolean;  
.  
.  
.  
Read (File, Result, 3);
```



# INSTRUCTOR NOTES

- AGAIN Element\_Type IS THE TYPE THE PACKAGE WAS INSTANTIATED WITH
- THE MODE MUST BE Out\_File OR Inout\_File.
- MISSING CODE FOR EXAMPLE

```
package Bool_IO is new Direct_IO (Boolean);  
use Bool_IO;  
File: File_Type;  
.  
.  
.  
Open (File, Out_File, "Data.Dat");
```

# Direct\_IO OPERATIONS

```
procedure Write (File : in File_Type;  
                Item : in Element_Type;  
                To   : in Positive_Count);
```

```
procedure Write (File : in File_Type;  
                Item : in Element_Type);
```

- FUNCTION

OUTPUT THE VALUE TO THE POSITION SPECIFIED BY THE CURRENT INDEX (THE VALUE OF TO IF SPECIFIED, THE NEXT POSITION OTHERWISE)

- EXCEPTIONS

Status\_Error, IF THE FILE IS NOT OPEN

Mode\_Error, IF THE MODE IS NOT Out\_File OR Inout\_File

- EXAMPLE

FILE BEFORE	CODE	FILE AFTER
TRUE		TRUE
FALSE		FALSE
FALSE	Write(File, TRUE,3);	TRUE
FALSE		FALSE

# INSTRUCTOR NOTES

- Set\_Index SETS THE CURRENT INDEX TO THE SPECIFIED VALUE.
- Index RETURNS THE VALUE OF THE CURRENT INDEX.
- Size RETURNS THE SIZE (NUMBER OF RECORDS) IN THE FILE
- End\_of\_File RETURNS TRUE WHEN THE CURRENT INDEX EXCEEDS THE SIZE OF THE FILE:  
FALSE OTHERWISE

# Direct\_IO OPERATIONS

```
procedure Set_Index (File : in File_Type;  
                    To   : in Positive_Count);  
  
function Index (File : in File_Type)  
    return Positive_Count;  
  
function Size (File : in File_Type)  
    return Count;  
  
function End_Of_File (File : in File_Type)  
    return Boolean;
```

# INSTRUCTOR NOTES

- REMIND THEM THAT A FILE IS ANYTHING THAT CAN SEND OR RECEIVE A VALUE. THE INTERNAL FILE OBJECT IS ASSOCIATED WITH THE EXTERNAL PHYSICAL FILE.
- THE COMMON COMMANDS ARE THE COMMANDS WHICH ALL THREE PACKAGES CONTAIN AND THAT WORK THE SAME FOR ALL THREE KINDS OF I/O.
- ASSIGN EXERCISE 32 OF THE EXERCISE BOOKLET.
- ASSIGN CHAPTER 13 OF THE PRIMER.

# I/O SUMMARY

- I/O OPERATES ON FILES, INTERNAL AND EXTERNAL
- THREE KINDS
  - Text\_IO
  - Sequential\_IO
  - Direct\_IO
- COMMANDS IN COMMON
  - Open, Close, Create,
  - Delete, Reset, Name,
  - Mode, Form, Is\_Open, End\_of\_File
- Text\_IO MAJOR COMMANDS
  - Get AND Put
- Sequential\_IO MAJOR COMMANDS
  - Read AND Write
- Direct\_IO MAJOR COMMANDS
  - Read AND Write

INSTRUCTOR NOTES

ALLOCATE AT LEAST ONE AND ONE HALF HOURS FOR LECTURE ON THIS SECTION.

THERE ARE NO ASSIGNMENTS AT THE END OF THIS SECTION. HAVE STUDENTS CONTINUE WITH PREVIOUS WORK.

THE PURPOSE OF THIS SECTION IS TO PROVIDE A READING KNOWLEDGE OF SOME OF THE MORE ADVANCED FEATURES OF THE LANGUAGE. IT DOES NOT ATTEMPT TO TEACH THESE CONCEPTS. THEY WILL BE COVERED IN LATER COURSES.

# **SECTION 16**

## **OVERVIEW OF OTHER LANGUAGE FEATURES**



## INSTRUCTOR NOTES

- STRESS THAT THE EXISTENCE OF A PRAGMA IS NOT ALLOWED TO CHANGE THE MEANING OF PROGRAM.  
  
A PROGRAM WITH A PRAGMA COMPILED BY ONE IMPLEMENTATION SHOULD "MEAN" THE SAME WHEN COMPILED BY A DIFFERENT IMPLEMENTATION (I.E. ONE THAT DOES NOT RECOGNIZE THE PRAGMA).
- MENTION THAT NOT ALL PRAGMAS ARE REQUIRED TO BE SUPPORTED BY THE COMPILER.
- APPENDIX F SPECIFIES WHICH PRAGMAS ARE SUPPORTED BY THE COMPILER.

## PRAGMAS -- BASIC IDEA

- CONVEY INFORMATION TO THE COMPILER
- SOME ARE LANGUAGE-DEFINED
- OTHERS ARE IMPLEMENTATION-DEFINED
- MAY AFFECT PERFORMANCE OF PROGRAM
- DO NOT CHANGE MEANING OF PROGRAM (I.E.,  
NO RESULTS PRODUCED)

## INSTRUCTOR NOTES

- "PACK ASKS THE COMPILER TO PACK AN OBJECT, E.G. AN ARRAY. In\_Line ASKS THE COMPILER TO EMBED THE CODE RATHER THAN HAVE SUBROUTINE CALLS."
- "PRAGMAS MAY APPEAR ANYWHERE IN THE DECLARATIVE PART OF A PROGRAM."
- UNDERSTANDING PRAGMAS IS NOT VITAL TO UNDERSTANDING THE LANGUAGE.
- EXAMPLES OF OPTIMIZE - TIME: GENERATE FAST CODE  
SPACE: GENERATE TIGHT CODE FOR LIMITED MEMORY.

## PRAGMAS --- EXAMPLES

- `pragma Pack (Type_Name);`
- `pragma Inline (Subprogram_Name);`
- `pragma Optimize (Time);`
- `pragma Optimize (Space);`
- `pragma Page;`

## INSTRUCTOR NOTES

RECURSIVE DATA STRUCTURES WERE MENTIONED BRIEFLY IN SECTION 10, ACCESS TYPES, AND ARE COVERED MORE THOROUGHLY IN L305.

"THE INCOMPLETE TYPE SPECIFICATION TELLS THE COMPILER TO ACCEPT THIS TYPE (I.E. ADD IT TO THE SYMBOL TABLE) EVEN THOUGH THE FULL DECLARATION HAS NOT BEEN SEEN."

USE YOUR PEN OR PENCIL TO COVER UP THE INCOMPLETE TYPE SPECIFICATION AND EXPLAIN THE CIRCULARITY PROBLEM. AFTER THE EXPLANATION, REMOVE THE PENCIL AND SHOW HOW THE INCOMPLETE TYPE DECLARATION SOLVES THE PROBLEM.

# USING ACCESS TYPES: LINKED LISTS

## CONTEXT:

```

type Vehicle_Type is (Ship, Tank, Plane);
type Vehicle_Record is
  record
    Type_Of_Vehicle   : Vehicle_Type;
    Weight            : Natural;  -- tons
    Date_Of_Acquisition : Date;
  end record;

```

## EXAMPLE:

```

type Vehicle_List_Entry; -- INCOMPLETE TYPE SPECIFICATION
type Link is access Vehicle_List_Entry;
type Vehicle_List_Entry is
  record
    V_Rec : Vehicle_Record;
    Next  : Link;
  end record;

```

P,Base : Link := null; -- INITIAL VALUE IS NULL EVEN IF NOT STATED EXPLICITLY

...

```

for Vehicle in Vehicle_Type
loop

```

```

  P := new Vehicle_List_Entry;
  P.V_Rec.Type_Of_Vehicle := Vehicle;  -- set up new entry
  P.V_Rec.Weight := 250;
  P.V_Rec.Date_Of_Acquisition := (3, 8, 1983);
  P.Next := Base;
  Base := P;
end loop;

```

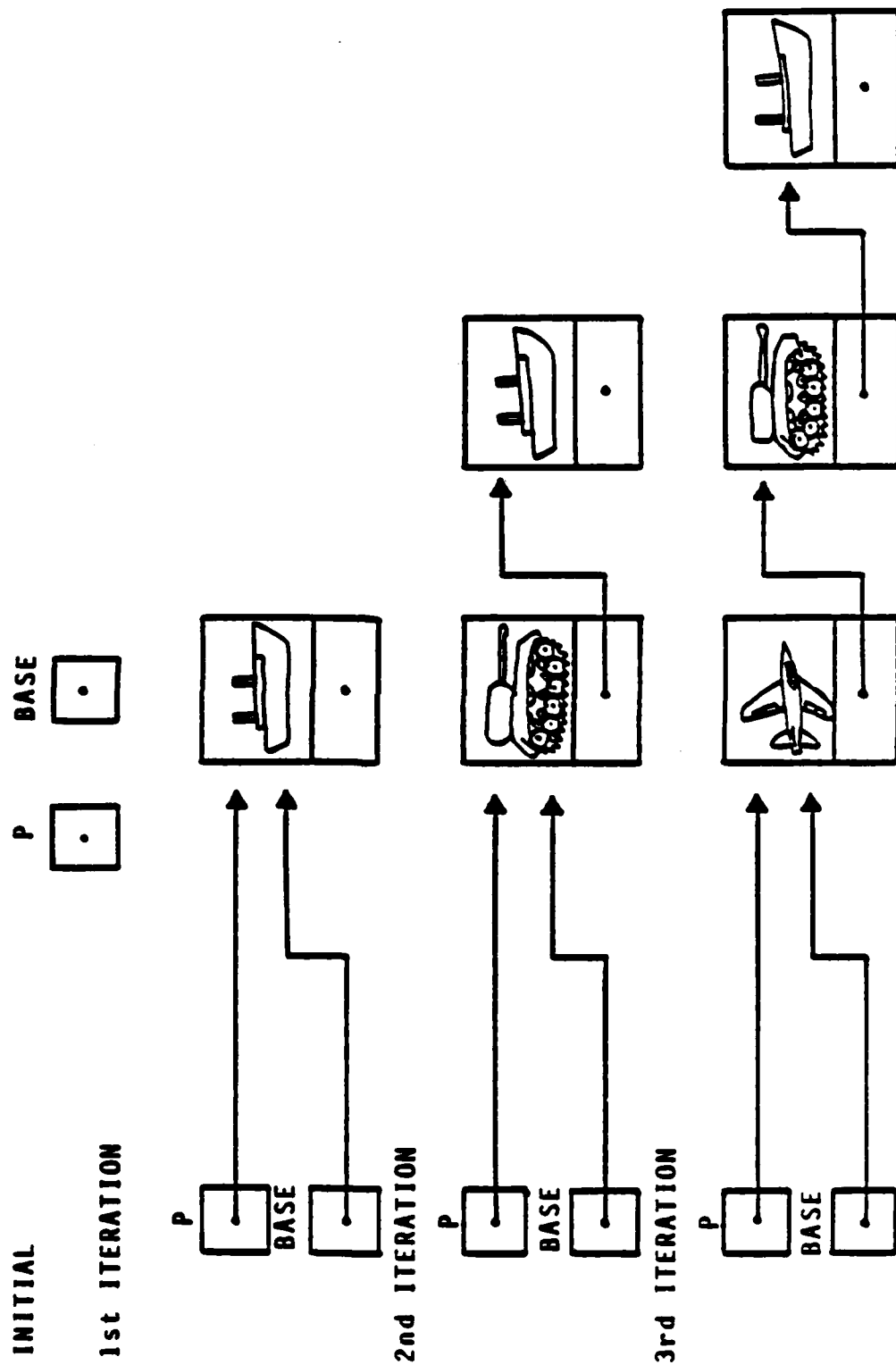
INSTRUCTOR NOTES

IF POSSIBLE, LEAVE THE SLIDE WITH THE CODE UP WHILE THIS IS EXPLAINED.

NOTE THAT THE OBJECTS ARE ADDED TO THE FRONT OF THE LINKED LIST.

"THE LINKED LIST EXISTS AS LONG AS THE OBJECTS ARE IN SCOPE.

# LINKED LIST DIAGRAM





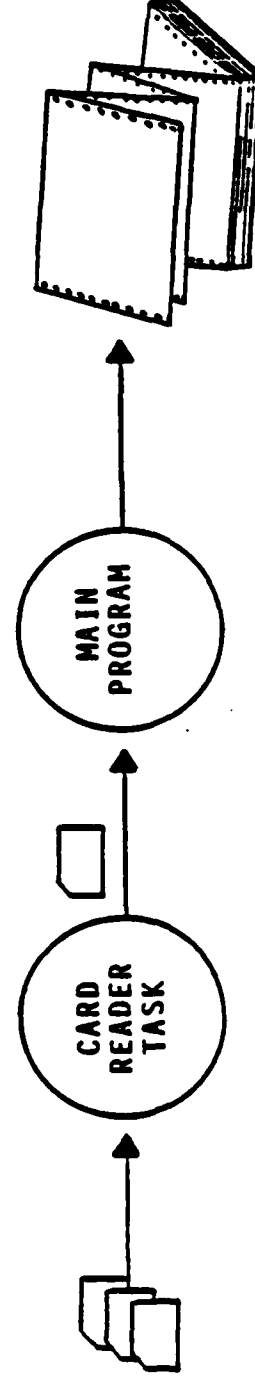
INSTRUCTOR NOTES

POINT OUT THAT THERE IS A PRAGMA CALLED PRIORITY WHICH CAN SET TASK PRIORITIES.  
IMPLEMENTATIONS ARE NOT REQUIRED TO SUPPORT THIS.

# TASKS -- BASIC IDEA

- TASKS ALLOW MULTIPLE THREADS OF CONTROL
- REAL OR APPARENT CONCURRENCY
- RENDEZVOUS FOR SYNCHRONIZATION AND EXCHANGE OF INFORMATION BETWEEN TASKS
- RUNTIME SYSTEM HANDLES TASK SCHEDULING

e.g COPY CARD IMAGES FROM "STANDARD INPUT" TO "STANDARD OUTPUT" --  
READING IS IMPLEMENTED AS TASK EXECUTING CONCURRENTLY WITH MAIN  
PROGRAM



INSTRUCTOR NOTES

ENTRIES ARE WHERE RENDEZVOUS CAN OCCUR. STATEMENTS MAY BE EXECUTED DURING RENDEZVOUS.

# TASK SYNTAX

```
task Task_Name is
.
.
.
end Task_Name;
```

## SPECIFICATION

- Visible Part
- Only Entry Declarations

```
task body Task_Name is
.
.
.
end Task_Name;
```

## BODY

- Hidden
- Additional Declarations
- Statements
- Accept Entries

# INSTRUCTOR NOTES

- REMIND THE STUDENTS THAT Card\_Reader KNOWS ABOUT Card BECAUSE ITS SCOPE IS AS IF IT WERE IN Main BECAUSE OF THF separate.
- "THE RENDEZVOUS COORDINATES THE Get AND Put."
- THE TASK IS ACTIVATED JUST PRIOR TO THE begin IN Main.

# MAIN PROGRAM

```

with Text_IO;
procedure Main is
  type Card is String (1 .. 80);
  C : Card;

  task Card Reader is
    entry Get (C: out Card);
  end Card_Reader;

  task body Card_Reader is separate;

begin -- Main
  loop
    Card_Reader.Get (C);
    Text_IO.Put (C);
  end loop;
end Main;

```

SPECIFICATION

BODY

ACCEPT

ENTRY  
CALL

# CARD READER TASK

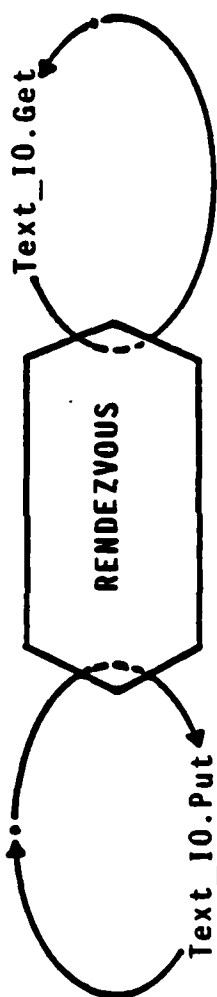
```

separate (Main)

task body Card_Reader is
  Latest_Card : Card;

begin -- Card_Reader
  loop
    Text_IO.Get (Latest_Card);
  accept Get (C : out Card) do
    C := Latest_Card;
  end Get;
  end loop;
end Card_Reader;

```



INSTRUCTOR NOTES

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## TASKS -- RENDEZVOUS

WHEN EITHER A CALLED TASK OR ITS CALLER ARRIVE AT A RENDEZVOUS POINT, THE ONE WHO ARRIVES FIRST WAITS FOR THE OTHER ONE

DURING THE RENDEZVOUS (THE EXECUTION OF THE STATEMENTS IN THE ACCEPT) THE CALLER IS SUSPENDED. THE CALLER RESUMES EXECUTION AFTER THE RENDEZVOUS IS COMPLETED.



INSTRUCTOR NOTES

"SELECT STATEMENTS ALLOW A TASK TO WAIT FOR MORE THAN ONE RENDEZVOUS."

# SELECT STATEMENTS

TASK CAN WAIT FOR ONE OF SEVERAL ALTERNATIVES

THREE FORMS

- SELECTIVE WAIT : TASK BEING CALLED
- CONDITIONAL ENTRY : CALLING TASK
- TIMED ENTRY : CALLING TASK

INSTRUCTOR NOTES

11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

## TASK TYPES -- BASIC IDEA

- ALLOWS THE USER TO CREATE A TASK TEMPLATE
- TASK OBJECTS CAN THEN BE CREATED FROM THIS TEMPLATE - OBJECTS ARE LIKE ANY OTHER TASK

# INSTRUCTOR NOTES

- POINT OUT THAT OBJECTS OF TASK TYPES ALSO BEGIN EXECUTION WITH THE begin STATEMENT.

# TASK TYPES -- BASIC IDEA

## EXAMPLE:

```
task type Simple_Channel is
    entry Send (M : in Message);
    entry Receive (M : out Message);
end Simple_Channel;

task body Simple_Channel is
    -- LIKE A TASK DEFINITION
end Simple_Channel;

Channel_1, Channel_2 : Simple_Channel;
.
.
.
Channel_1.Receive (Msg); -- GET A MESSAGE
Channel_2.Send (Msg); -- AND SEND ON OTHER CHANNEL
```

INSTRUCTOR NOTES

POINT OUT THAT THESE ARE LOW LEVEL FEATURES OF THE LANGUAGE.

# REPRESENTATION SPECIFICATIONS -- BASIC IDEA

- MAP ABSTRACT DATA TO PHYSICAL HARDWARE
- DECLARED AFTER THE ITEMS THEY REPRESENT
- CAPABILITIES:
  - SPECIFY INTERNAL CODES FOR LITERALS OF AN ENUMERATION TYPE
  - SPECIFY RECORD LAYOUT
  - SPECIFY AMOUNT OF STORAGE ASSOCIATED WITH A TYPE
  - SPECIFY REQUIRED STORAGE ADDRESS FOR AN ENTITY



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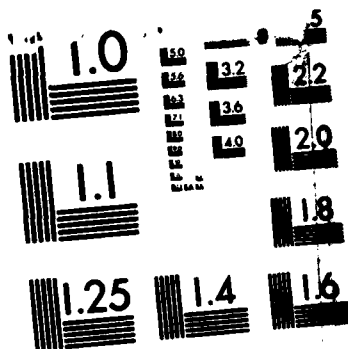
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## INSTRUCTOR NOTES

- POINT OUT THAT THE INTEGER CODES SPECIFIED FOR THE TYPE MUST HAVE THE SAME ORDERING AS THE ENUMERATION LITERALS.

I.E.

AN ENUMERATION CLAUSE FOR Boolean CANNOT BE

for Boolean use (False => 1, True => 0);

BECAUSE False MUST HAVE A VALUE LESS THAN True. POINT OUT THAT THE TWO REPRESENTATION CLAUSES ARE JUST TWO WAYS OF STATING THE SAME THING.

# ENUMERATION TYPE REPRESENTATION CLAUSES

- MAPPING FROM ELEMENTS OF A TYPE TO SPECIFIC INTERNAL CODES

type Op\_Codes is ('00, ST0, ADD, SUB, JNZ);

for Op\_Codes use (1, '0, 11, 12, 15);

# INSTRUCTOR NOTES

- at CLAUSE IS USED TO SPECIFY AN OBJECT'S PHYSICAL ADDRESS
- ALIGNMENT CLAUSE SPECIFIES STORAGE BOUNDARY FOR THE RECORD

# RECORD TYPE REPRESENTATION CLAUSES

- MAPS
  - ORDER OF RECORD COMPONENTS
  - COMPONENT POSITION
  - COMPONENT SIZE
  - GLOBAL ALIGNMENT OF RECORD
- at CLAUSE
  - LOCATES COMPONENT RELATIVE TO START OF RECORD
  - MEASURED IN STORAGE UNITS
- RANGE IN BITS
  - LOCATION AND EXTENT OF A COMPONENT RELATIVE TO A STORAGE\_UNIT
- ALIGNMENT CLAUSE
  - STORAGE BOUNDARY FOR BEGINNING OF AN OBJECT

INSTRUCTOR NOTES

# LENGTH SPECIFICATION

- USED TO OVERRIDE THE AMOUNT OF STORAGE NORMALLY ASSOCIATED WITH AN ENTITY
- ATTRIBUTES
  - DATA TYPE
    - T'Size : NUMBER OF BITS FOR OBJECTS OF TYPE T
  - ACCESS TYPE
    - T'Storage\_Size : NUMBER OF STORAGE UNITS TO BE RESERVED FOR ALLOCATING OBJECTS
  - TASK OR TASK TYPE
    - T'Storage\_Size : NUMBER OF STORAGE UNITS TO BE RESERVED FOR EACH ACTIVATION OF THE TASK OBJECT
- for Attribute use Integer\_Expression;  
for Vehicle\_Record'Size use 1000;



## INSTRUCTOR NOTES

- "THE REPRESENTATION CLAUSE MUST APPEAR AFTER THE DECLARATION OF THE ENTITY IT REFERS TO. IT MUST BE IN THE SAME DECLARATIVE REGION."

FOR EXAMPLE:

```
declare
type Rec is
record
    Cl : Boolean;
end record;
begin
declare
for Rec use -- **ILLEGAL
record at mod 2
    Cl at 0 range 0 .. 0;
end record;
begin
    null;
end;
null;
end;
```

# ADDRESS SPECIFICATION

- SPECIFIES THE LOCATION OF AN OBJECT IN STORAGE
  - SPECIFIES THE STARTING ADDRESS OF A PROGRAM UNIT
  - CAN BE USED TO ASSIGN AN ENTRY TO A HARDWARE INTERRUPT
- FORMAT:

for Name use at Interrupt\_Address;

- Name IS

- OBJECT

- SUBPROGRAM, PACKAGE, OR TASK

- ENTRY

e.g.

for Boot\_Program use at 256;

task Fire\_Control\_Interrupt\_Handler is  
entry Fired;  
for Fired use at 176;  
end Fire\_Control\_Interrupt\_Handler;

# INSTRUCTOR NOTES

THE INTERFACE PRAGMA IS A WAY OF TELLING THE COMPILER THAT A SUBPROGRAM BODY IS WRITTEN  
IN SOME OTHER LANGUAGE, E.G. ASSEMBLER OR FORTRAN.

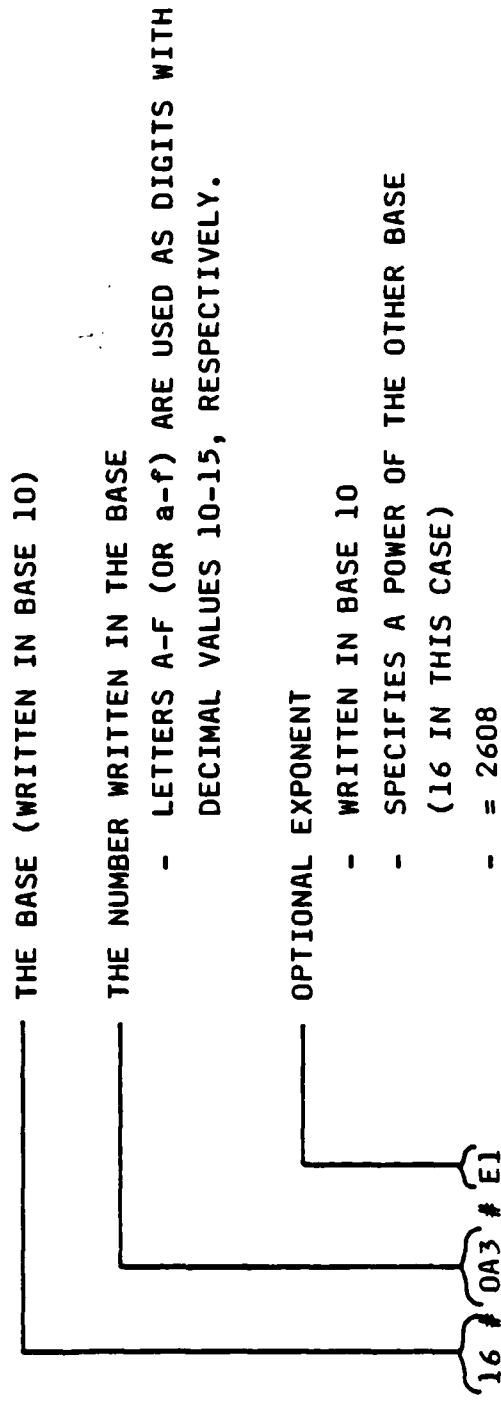
# MACHINE CODE INSERTIONS -- BASIC IDEA

- Ada PERMITS INSERTION OF MACHINE CODE INSTRUCTIONS, USING THE CODE STATEMENTS
- CODE STATEMENTS ARE RECORD AGGREGATES WHOSE COMPONENTS CORRESPOND TO FIELDS OF A MACHINE LANGUAGE INSTRUCTION.
- SPECIFICS ARE IMPLEMENTATION-DEPENDENT
- CAN ONLY BE USED IN A PROCEDURE IN WHICH THERE ARE NO DECLARATIONS AND EVERY STATEMENT IS A CODE STATEMENT.
- SHOULD BE USED ONLY FOR VERY SHORT SEQUENCES OF MACHINE LANGUAGE INSTRUCTIONS (1-5 INSTRUCTIONS). FOR LONGER SEQUENCES, WRITE AN ASSEMBLY LANGUAGE MODULE AND USE THE INTERFACE PRAGMA.
- IN GENERAL, A VERY CLUMSY WAY OF WRITING MACHINE INSTRUCTIONS IN Ada.

INSTRUCTOR NOTES

# BASED NUMBERS -- BASIC IDEA

- NUMERIC LITERALS THAT ARE WRITTEN IN BINARY, OCTAL, OR HEXADECIMAL (OR ANY OTHER BASE FROM 2 TO 16.)
- MAY BE APPROPRIATE WHEN DEALING DIRECTLY WITH HARDWARE OR WITH ASSEMBLY LANGUAGE SOFTWARE.
- BASED INTEGER LITERAL (NO RADIX POINT, EXPONENT MAY NOT BE NEGATIVE):



- BASED REAL LITERAL (RADIX POINT WITH AT LEAST ONE DIGIT ON EACH SIDE):  
2#0.1#E-3      (- (1/2) \* 2.0 \*\* (-3) = 1/16)

INSTRUCTOR NOTES

## USE OF BASED NUMBERS

for Boot\_Program use at 16#0100#; -- in Address Specification  
for Fired use at 16#0A30#; -- associated with Task Entry Specification



END

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**INFORMATION**

AD - A166366  
Material: Basic Ada Programming (L202), Volume I ~~AD-166366~~

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Comments:

3. Were there any typographical errors?

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If yes, on what pages?

4. Was the material organized and presented appropriately for your applications?

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